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OPTICAL TOOLS COMPUTERIZED DESIGN AND MANUFACTURE

by

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Manufacturing Technology Directorate

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This project has been accomplished as part of the US Army Manufacturing Methods and Technology Program, which has as its objective timely establishment of manufacturing processes, techniques, or equipment, to insure the efficient production of current or future defense programs.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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Lens manufacture	Pitch buttons	Polishers
CAD	Pitch blocks	
CAM	Blockers	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the design, manufacture, and use of tooling used in the production of precision lenses. A computer program is presented which will provide tooling design based on lens specification input and from which a tape for NC manufacture of the tools can be produced. Economic data is presented on tooling made from the computer design using simulated NC methods.

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INTRODUCTION

The work covered by this report is a two part effort. The first part is devoted to establishing design standards for optical finishing tools, and part two is devoted to the manufacture of these tools and their use to make optical elements. The ultimate objectives are to reduce tool cost per optical element produced, and to reduce optical tool inventories so that less storage space is required.

The frequency of occurrance per 100 optical elements in fire control instruments is approximately 57 lenses, 16 prisms, 9 windows, 7 mirrors and 11 other. Tooling used in lens manufacture was therefore selected for study and improvement.

A review of lenses manufactured at the Frankford Arsenal optical facility between 1 January 1970 and 30 December 1973 showed that approximately 40,000 lenses were made in lot sizes varying from 10 to 1600 pcs. Most lot sizes were between 50 and 400 pcs (approximately 90%) and approximately 70% of the lenses had a finished diameter between 0. 750 and 1. 500 inches. All efforts in this study have been oriented toward the largest percentages cited above.

For clarity, the following GLOSSARY of terms is provided.

1. Generate: The act of forming a spherical surface on a lens blank.

2. Generating Chuck: Tool for holding a lens blank for generating.

3. Pitch Block: Block for holding lens blank in proper orientation for grinding and polishing operations using pitch buttons for retention.

4. Pitch Buttons: Pitch molded on the obverse side of lenses to hold them in place for finishing operations.

5. Pitch Button Mold: Tool for molding pitch buttons on lens blank.

6. Blocker: Spherical tool for precise positioning (curved radii) on pitch blocks.

7. Spot Block: Block with machined cavities for positioning and holding lens blank.

8. Spot: Machined cavity in spot block for retention and precise positioning of lens blank.

9. Grinder: Precision spherical lap for fine grinding lenses.

10. Polisher: Precision spherical lap for polishing lenses.

11. Test Glasses: Precise optical elements used for gaging optical work in progress.

Lens blanks are cored from plate or molded, individually generated, mounted on pitch blocks and "gang" finished. All lens surfaces are finished to within three Newton interference rings of the appropriate Test Glass. This tight tolerance is of particular significance in the case of couplets whereby two lenses are bonded together.

Test glasses, for a particular curve, are made in matching parts to within one Newton ring of each other.

Using existing practices, lens tooling design (including drawings) requires approximately two hours per tool per curve. Calculations are necessary to determine lens blank distribution on mounting blocks and pertinent dimensions of all tools.

Except for curve generation, lens tools are manufactured using conventional machine shop methods. After fabrication, the spherical surfaces of Grinders and Blockers require a "wearing in" process to obtain the necessary precision as indicated above. A Polisher consists of pitch or wax contained by a metal shell that is formed, while heated to its flow temperature, by the surface to be polished.

The operational advantages of using Spot Blocks is well known, however the cost of such tooling has previously been so high as to preclude their use except in large production quantities.

Initial efforts were directed toward making Spot Blocks more universal, i.e., capable of being used on a variety of lens radii. Though some advantages developed, it became apparent that the approach was not economically feasible. Efforts were then directed toward computerized design and N/C manufacture of lens tools.

> Note: The use of Spot Blocks causes a change in the lens manufacturing procedure as is shown on Chart II. For the remainder of this report the "Spot Block Method" and the current or "Pitch Button Method" shall be referred to as Method A and Method B, respectively.

UNIVERSAL TOOLING

A universal spot block (Figure 1) was designed, fabricated and used under trial conditions. It utilized replaceable inserts that could be made to accommodate convex radii between 1. 5 and 2 inches. Two sets of inserts were made to mount lens blanks whose radii were 1. 688 and 1. 994 inches respectively. Lenses were made following Method A procedures delineated on Chart II. The quality of the lenses produced was good in all respects.

A comparison of this method with the conventional Method B showed that the grinding and polishing times of the two methods was the same. Method A indicated advantages in the set up and curve generating times, and the elimination of tools such as: Blockers, Pitch Button Molds and Generating Chucks. However, major difficulties arose. Spot Blocks made with removable inserts have a fixed number of spots dictated by the lens outside diameter and the shortest radius that can be accommodated by that block. This results in a less than optimum use of the surface area developed by blanks with the same O. D. and longer radii. New inserts or new blocks must be made for each lens curve and diameter combination, and the result is additional design and fabrication times. In addition, the inventory and storage problems are increased. The benefits of lens fabrication using Method A are offset by the above problems, and the unit tool cost is increased rather than decreased. In order to take advantage of the benefits of Method A over Method B found in lens fabrication, another approach to reducing optical tool costs had to be found. It was determined that this reduction could be achieved with computerized tool design and N/C manufacture.

COMPUTERIZED TOOL DESIGN

Mathematics (Appendix A) suitable for computerizing was developed to calculate design parameters for Spot Blocks, Grinders and Polishers. Application of the mathematics to lens drawing data, i. e. , outside diameter, center thickness, and curve radii with a sign (±) convention to indicate form (convex, concave) results in all dimensions, including the precise distribution of spots on a block (Figures 2 and 3), required to fabricate tools for that lens.

A recently completed study, Project #6737062 F. A. report TR 75067 titled 'Radial Pressure Conversion of an Optical Polishing Machine" authored by Martin H. Horchler, showed that lenses block mounted beyond an 80° angle to the axis of the block measurably extended the grinding and polishing times for that block. Vertical forces (weights) are used in these operations, and the resultant normal forces on the surfaces being worked on falls below 20% of the total force applied (Figure 4). Hence, a limit of 160° included angle was accepted as a design constraint along with a limit of 10 inches in block diameter which is dictated by the geometry of most available optical fabrication equipment.

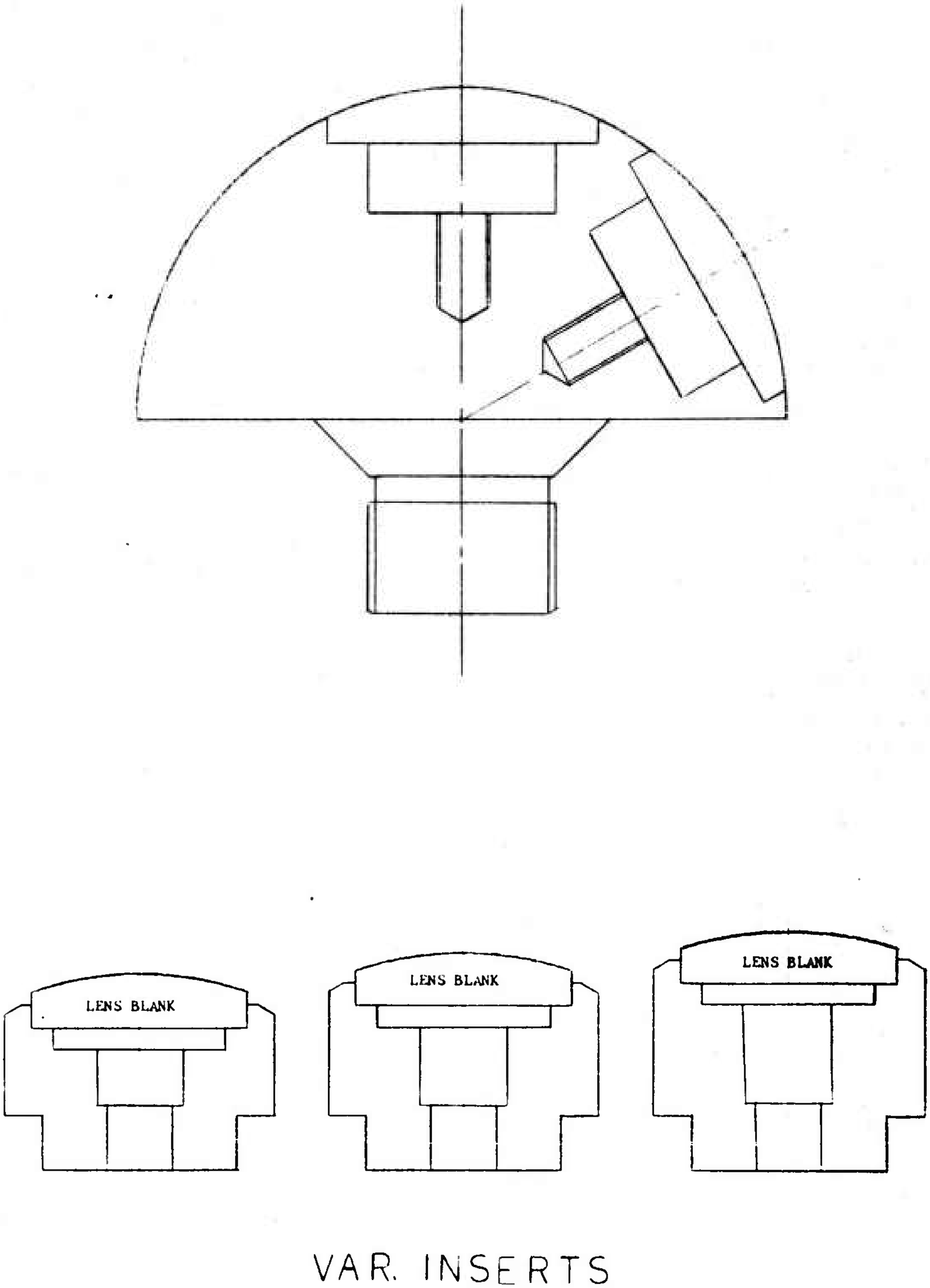

Figure 1. Universal Spot Blocks, Variable Inserts

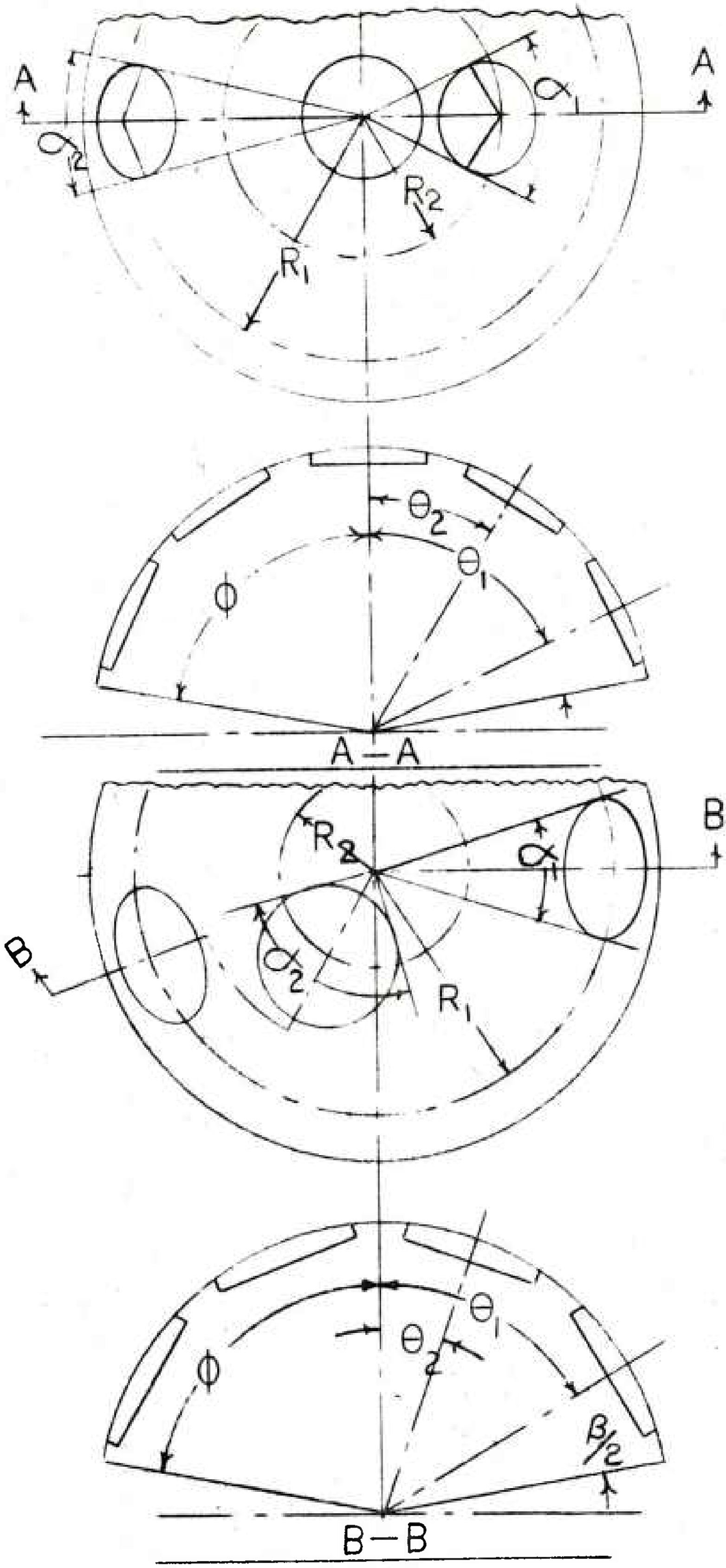

Figure 2. Distribution of Spots - Convex

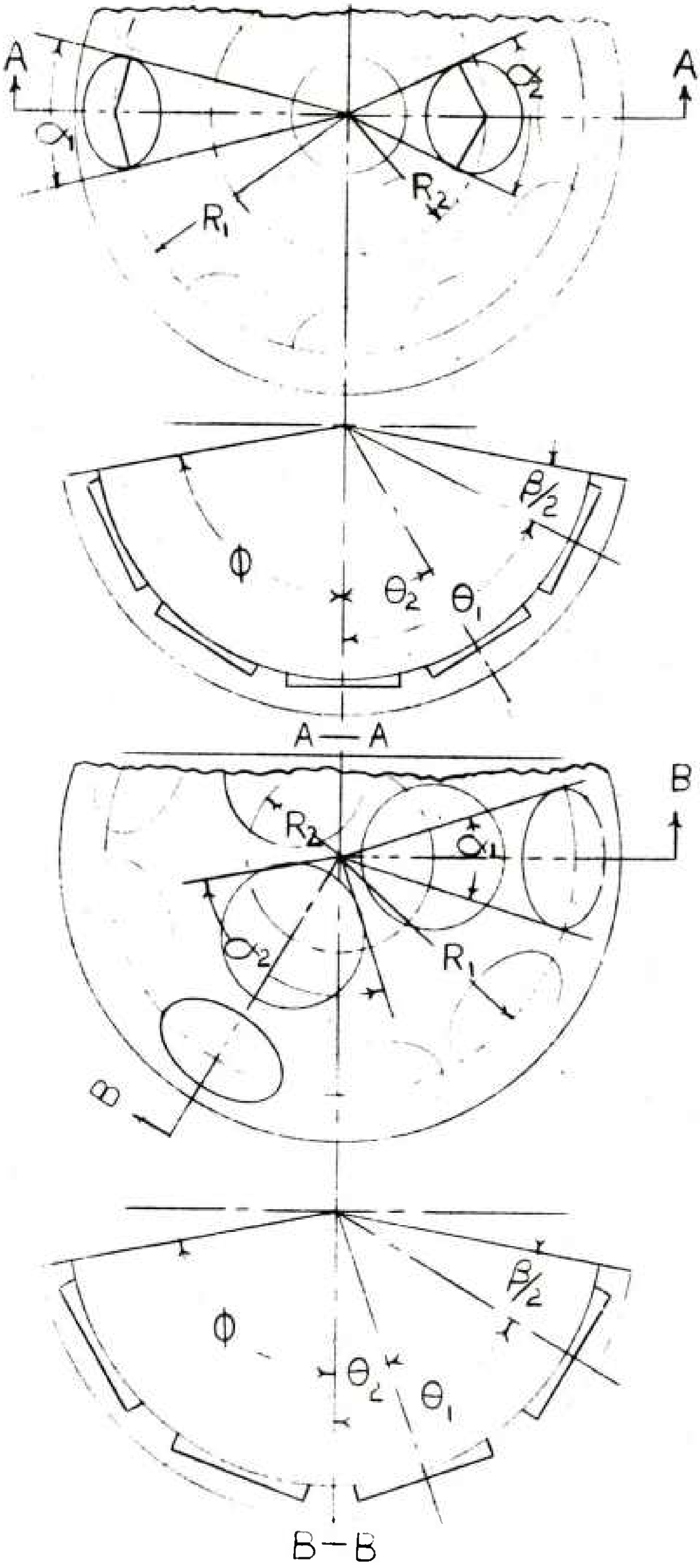

Figure 3. Distribution of Spots - Concave

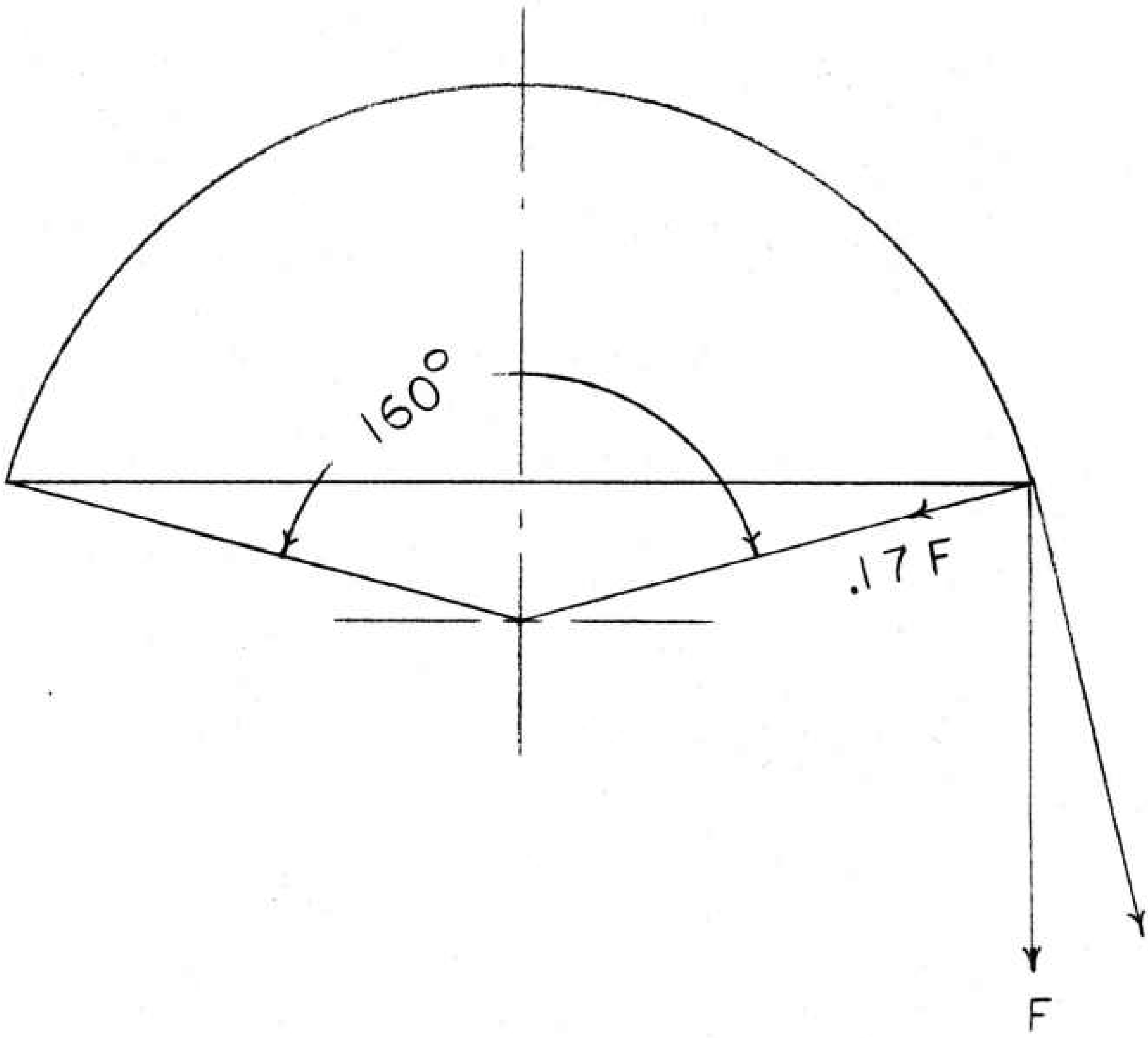

Figure 4. Limiting Angle Diagram

The project was directed at developing N/C programs for a Wadell Lathe for turning and contour work and a Cincinnati Cim-X equipped with a programmable Walter universal rotary table with tilt capabilities for machining Spots. All lens tools were designed to be mounted on a common adapter (Figure 5) so that a datum could be established for both fixturing and calculating parameters.

The mathematics was further developed to compute position parameters for the above equipment such as: angular tilt increments, angular rotational incrcments, and Cartesion coordinates for tool to work piece orientation (Figures 6 and 7). In addition, lens blank dimensions are calculated to have excess material for finishing and sized so that standard sized end mills can be used for milling spots. Concave Spot Blocks presented a problem in that the criterion of a 160° included angle of the spherical sector could not be strictly adhered to because of the machine geometry (Figure 8). Hence, the mathematics was adjusted to find the best angle possible.

The mathematics was programmed (Appendix B) in Fortran IV language for a Control Data 6500 computer utilizing a Fortran compiler. Included in the program is a geometric priority selector (see Figure 12).

After debugging, sample computer runs were made (Appendix D), and spot checked for accuracy. The input consisted of lens data as described above and the output included the input data for identification plus all parameters necessary to program N/C equipment for the fabrication of Spot Blocks, Grinders and Polishers.

TOOL MANUFACTURE AND USE

Production time was not available on either the Wadell or the Cim-X (NC machine) when needed; therefore, rather than delay the project, simulated automation was decided on. The reasoning was that a programmed N/C machine can follow explicit instructions more efficiently than an operator; therefore, if an operator can successfully produce a spot block by carrying out indicated moves without recourse to intermittent measurements, success on N/C equipment is assured.

A Kearny and Trecker Milling Machine equipped with a Model H universal dividing head was selected for the milling work, and a Strasbaugh curve generator was selected for the contour work. Turning was done on an engine lathe. Since the geometry of the milling machine to be used in the simulation differs from that of the N/C equipment, it was necessary to include the proper mathematics for cutter to workpiece orientation in the computer program (Figures 9 and 10). This series of calculations has been left in the program and the results may be seen in the computer outputs shown in Appendices C and D.

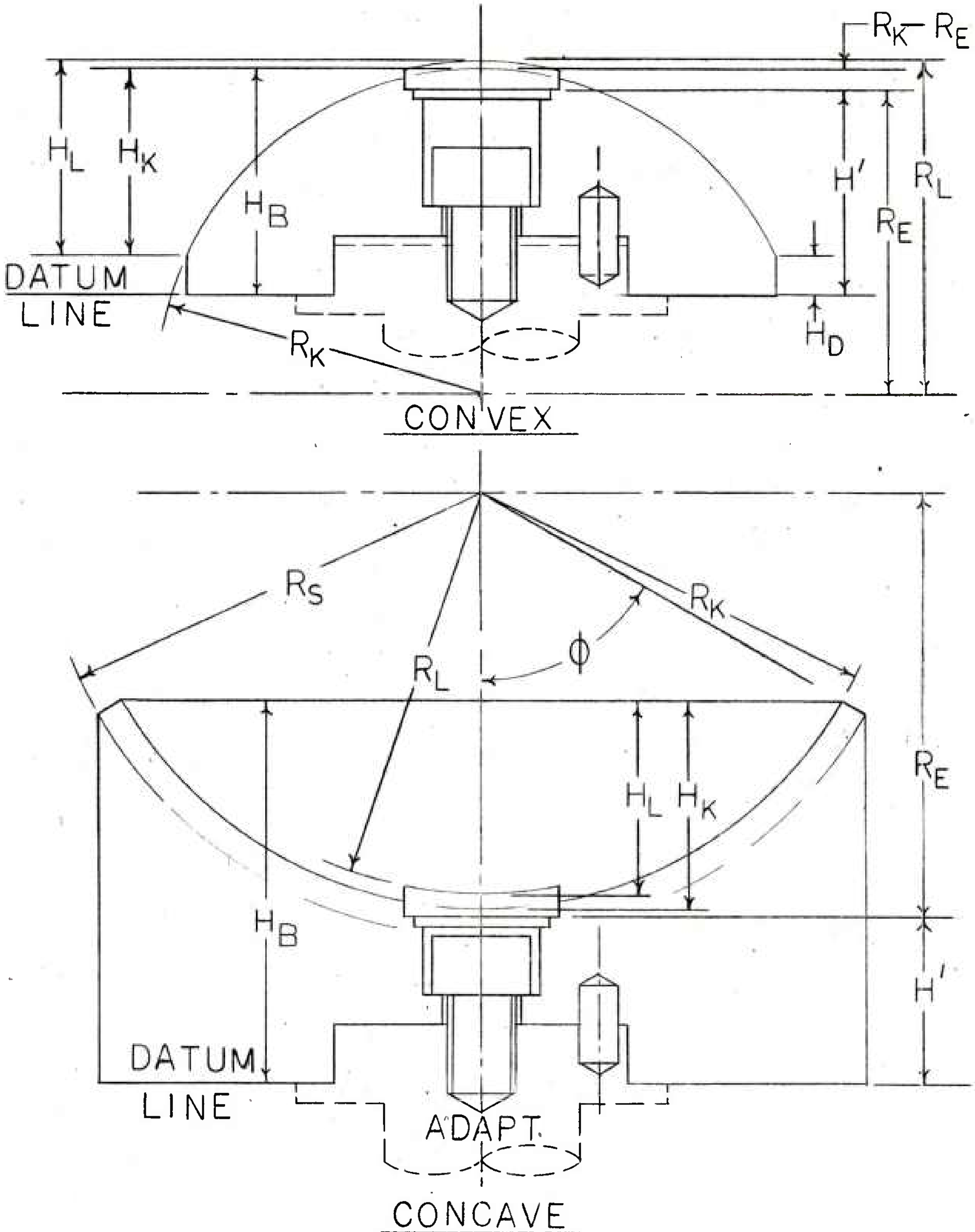

Figure 5. Universal Adapters (Datum)

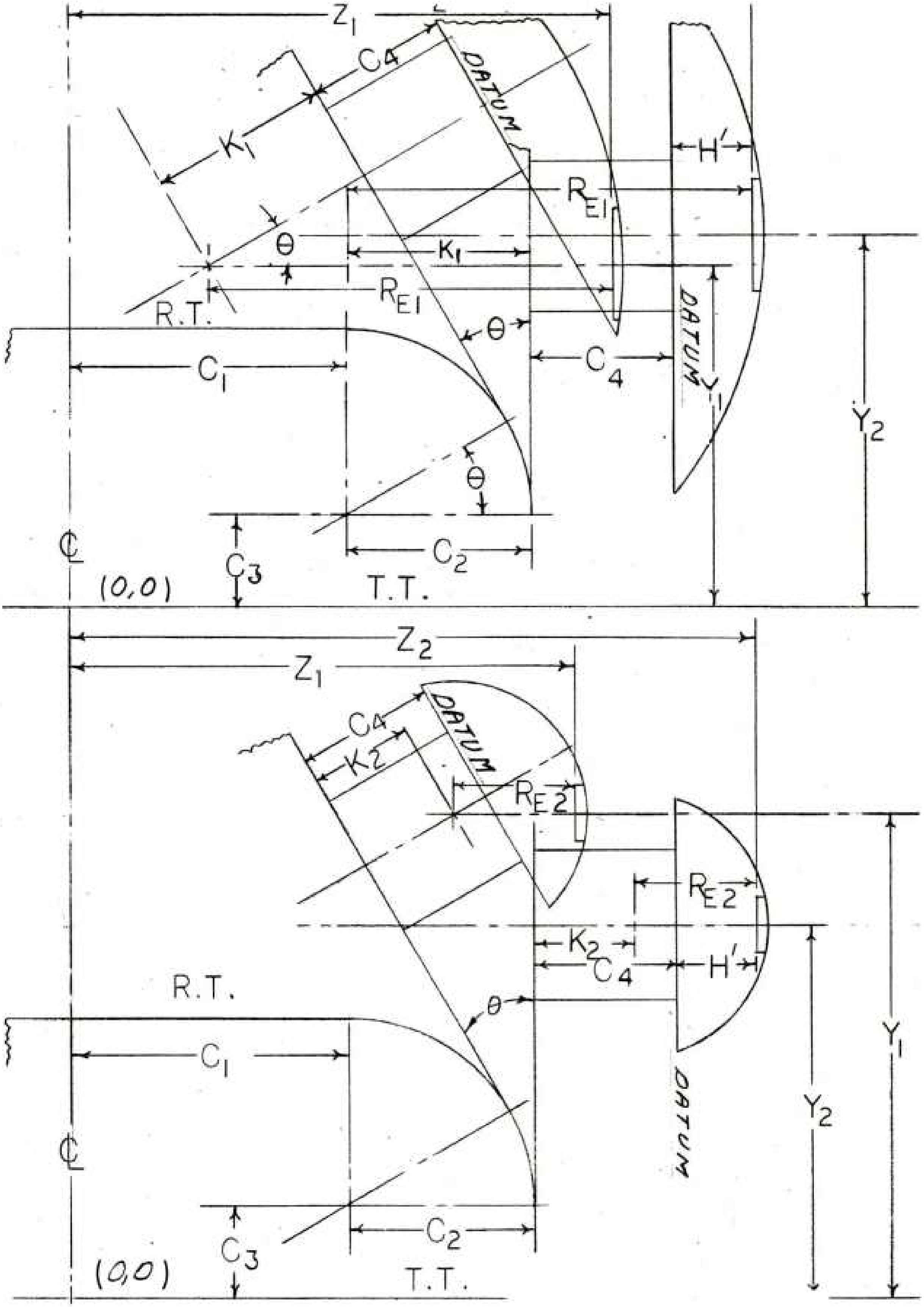

Figure 6. Cim-X Geometry - Convex

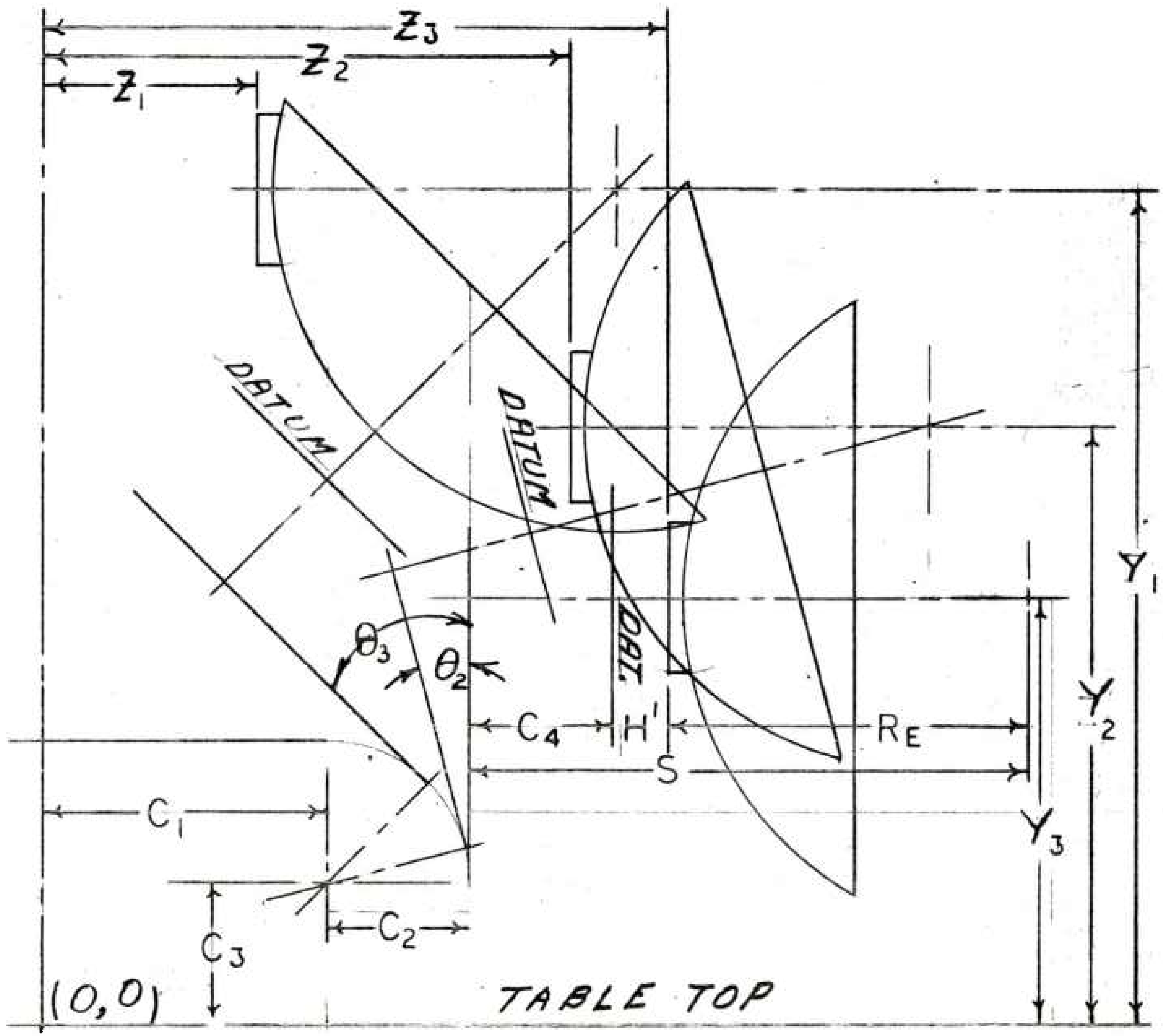

Figure 7. Cim-X Geometry - Concave

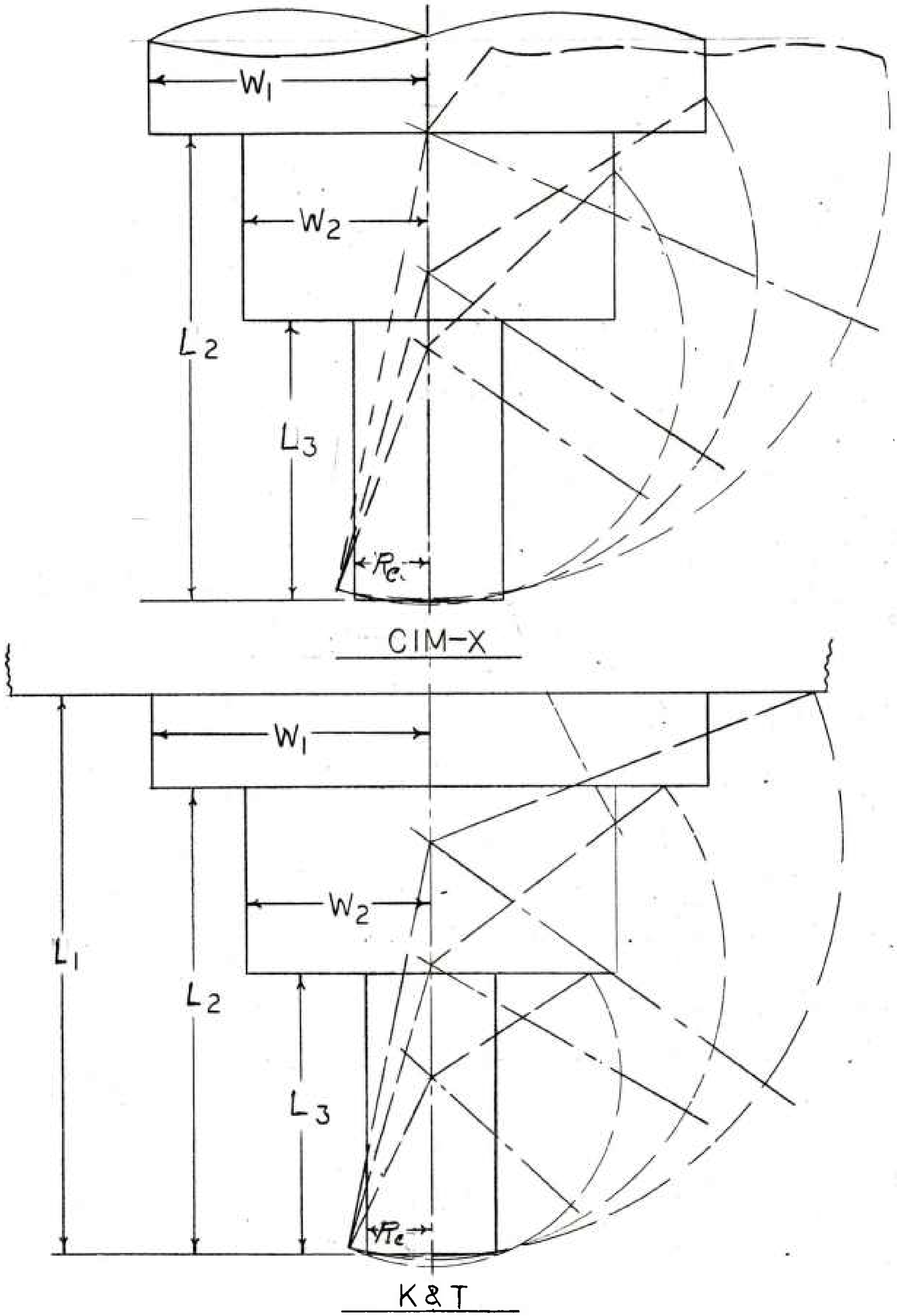

Figure 8. Tool Clearance Geometry - Concave

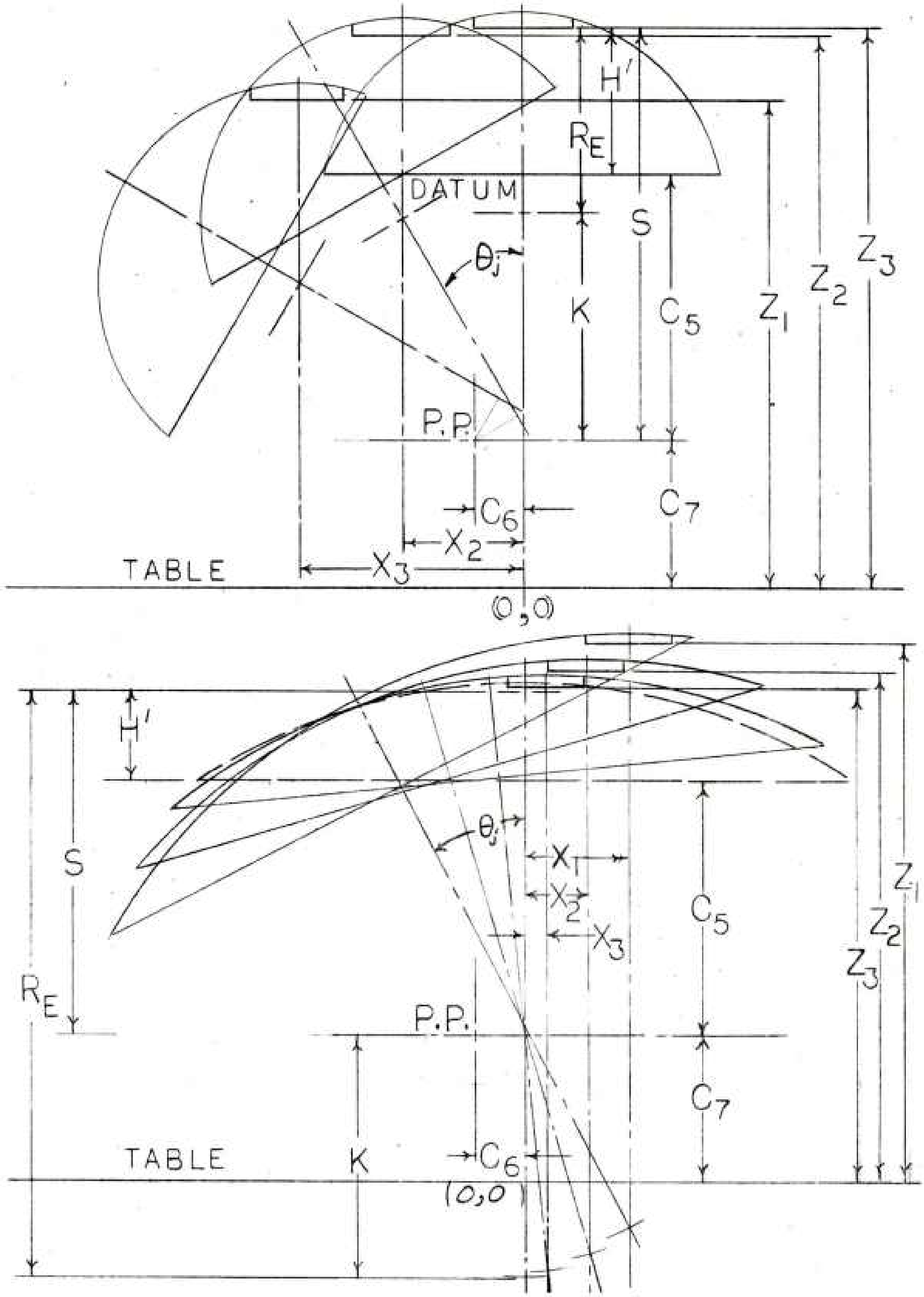

Figure 9. K & T Geometry - Convex

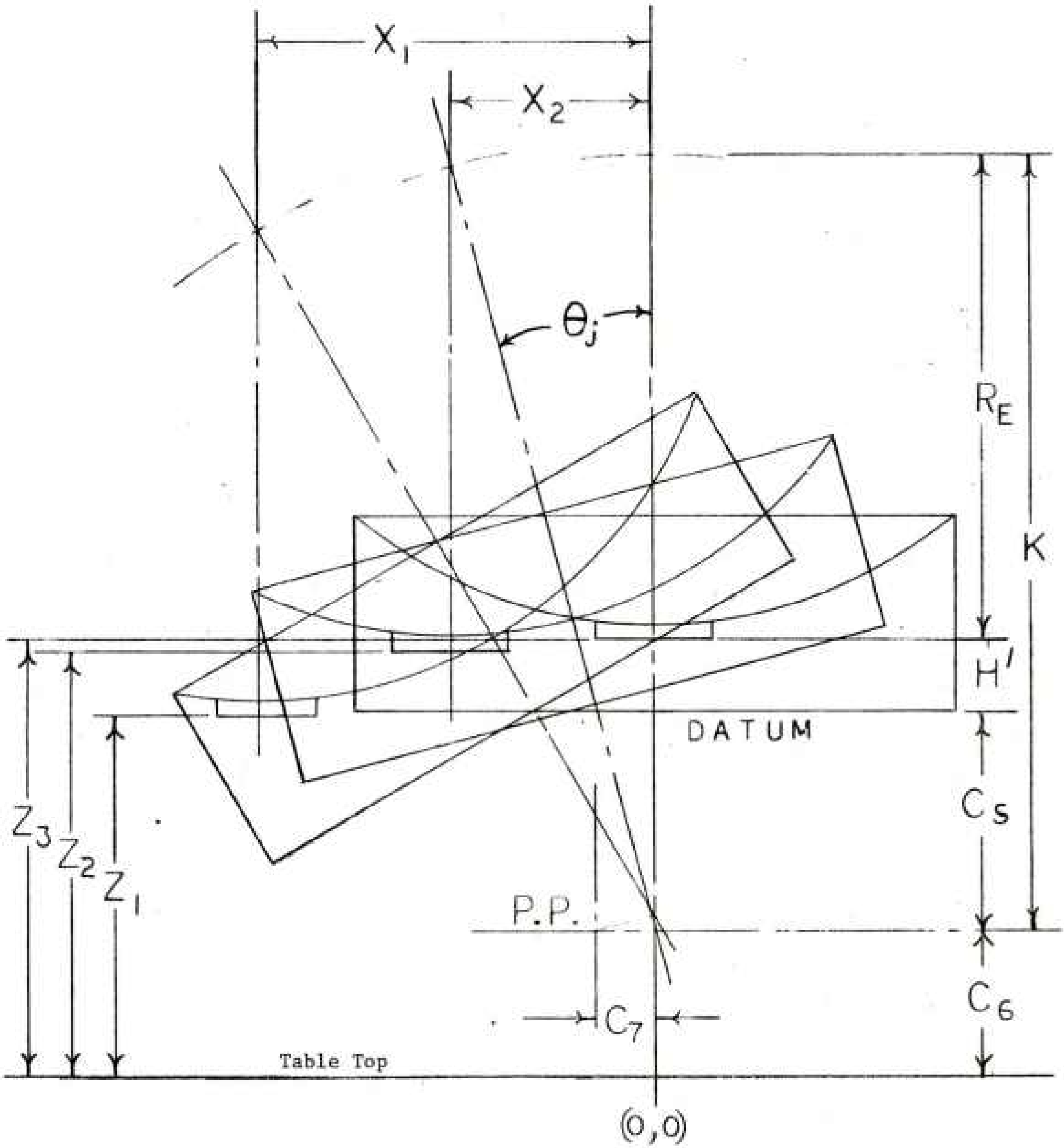

Figure 10. K & T Geometry - Concave

Computer runs were made for selected lenses and the output information was used to make optical tools. Since both Method A and Method B use the same basic grinder and polisher configuration, only spot blocks were actually made. All of the "spot" milling was done with two-lipped end mills. This type of cutter permits a straight in feed obviating the need for boring or drilling pilot holes, and results in a flat bottom shouldered cavity. After initial setup, all operations were carried out using manual adjustments as dictated by the computer output. No drawings were used.

A prototype lens production line was set up such that: lens blanks were cored out of glass plate, blanks were mounted on spot blocks using a temporary bonding cyanoacrylate adhesive, and curves were "gang" generated on the blanks preparatory to the grinding and polishing operations. The grinding and polishing operations were carried out on a sufficient number of blocks to confirm design integrity and collect data.

Some blocks were successfully used by M. Horchler*, and will be reported on elsewhere.

METHOD A VS. METHOD B

This cost comparison of the two methods of lens manufacture is made on the basis of manhours, and is subject to the following assumptions:

1. The factors used for Method A shown on Charts I and II are derived from experience gained in this study; however, the set up and machine times for N/C equipment were extrapolated from actual set up and machine times recorded.

2. The criteria for corresponding data used for Method B was estimating charts prepared by the F. A. Production Engineering Section from historical data recorded over a long period.

3. An APT or UNI-APT N/C tape preparation system can be used to prepare N/C tapes from design parameters developed in Program STBLK Appendix B.

4. Costs for universally used tools for both methods such as: fixtures, adapters, pitch button molds, generating chucks, etc. have been omitted. These tools are permanent in nature, and their costs per lens produced approaches zero as usage increases.

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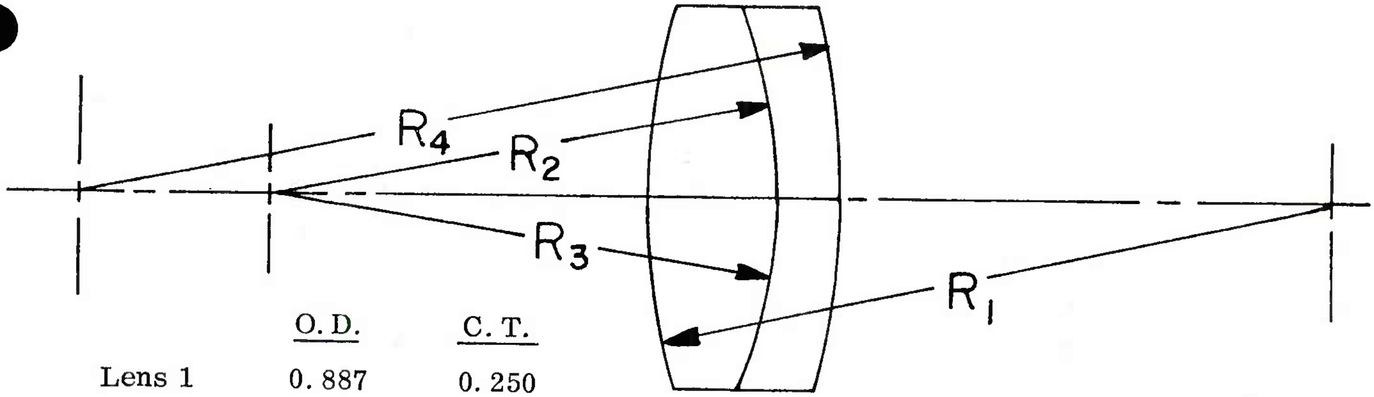
*"High Speed Fabrication of Precision Optics" MM&T Project #6747463, by M. Horchler, August, 1976.

5. The comparison data shown on Tables 1 and 2 are complete in all essential details. Minor operations common to both methods have been omitted as irrelevent. Hence, the hours shown for each method should be considered as estimates of the two methods.

6. An achromatic couplet, as shown on Figure 11, was selected as a typical example for this comparison. The tool requirements shown are predicated on the results shown in Appendix C.

7. Application of the factors shown on Charts I and II, on the typical sample, results in Charts III and IV.



	O. D.	C. T.
Lens 1	0. 887	0. 250
Lens 2	0. 887	0. 046

TOOL REQUIREMENTS
(Lot Size 200)

RADII	BLANKS/BLK.	BLOCKS	GRINDERS	POLISHERS
R_1 (2. 542)	25	4	2	2
R_2 (1. 300)	6	12	4	6
R_3 (-1. 300)	7	12	4	6
R_4 (3. 350)	49	2	1	2
	TOTALS	30	11	16

TOOL DESIGN REQUIREMENT	METHOD A	METHOD B
1 ea. rad.	4 Spot Blocks	4 Pitch Blocks
1 ea. rad.	4 Grinders	4 Grinders
1 ea. rad.	4 Polishers	4 Polishers
TOTALS	12	12

TOOL MANUFACTURE REQUIREMENT

	METHOD A	METHOD B
	30 Spot Blocks	30 Pitch Blocks
	11 Grinders	11 Grinders
	16 Polishers	16 Polishers
TOTALS	57	57

Figure 11. Sample Lens Tool Requirements

CHART I

TOOL DESIGN-MANUFACTURE PROCEDURE
TIME IN MAN HOURS

	"METHOD A" SPOT BLOCKS TOOLS						"METHOD B" PITCH BUTTON TOOLS					
	Spot Block		Grinder		Polisher		Spot Block		Grinder		Polisher	
OPERATION	Set up	Unit	Set up	Unit	Set up	Unit	Set up	Unit	Set up	Unit	Set up	Unit
Prepare[1] Computer Input	----1.0----		Includes all tools				-	-	-	-	-	-
Computer[1] Run	----0.5----		Includes all tools				-	-	-	-	-	-
Prepare tspes	1.0	-	0.5	-	0.5	-	-	-	-	-	-	-
Design & Prepare Dwgs	-	-	-	-	-	-	---- 2.0 hours per each different tool ----					
Turn Taper & the End	-	-	-	-	-	-	2.0	1.5	Includes all tools			
Face & Bore for Adapter	1.0	0.5	Includes all tools				-	-	-	-	-	-
Assemble Adapter	0.5	0.5	Includes all tools				-	-	-	-	-	-
Turn & Face[2]	1.0	0.5	Includes all tools				1.0	1.25	Includes all tools			
Generate[3]	-	-	-	-	-	-	1.0	1.25	Includes all tools			
Mill Spots[4]	1.0	0.33 Per individual spot					-	-	-	-	-	-
Break In	-	-	-	4.0	-	-	-	-	-	4.0	-	-
Form	-	-	-	-	1.0	1.0	-	-	-	-	1.0	1.0

Notes:

(1) The computer design time is a minimum. Tools for as many as ten different size lenses can be designed in the same time.

(2) Turn face and generate are done on the same set up in Method A. Add 0.5 hours set up time for each different size tool after initial set up.

(3) Add 0.5 hours set up time for each different size tool after initial set up in Method B.

(4) Add 0.5 hours set up time for each different size spot block after initial set up.

CHART II
LENS MANUFACTURING PROCEDURE
TIME IN MAN HOURS

	"METHOD A"							"METHOD B"						
	Step	Set up Time	Unit Time	Blanks per Block 6	12	25	50	Step	Set up Time	Unit Time	Blanks per Block 6	12	25	50
Core Cut Blanks	1	1.0	0.05	Unit time X lot size				1	1.0	0.05	Unit time X lot size			
Generate Curve 1	N.A.	-	-	-	-	-	-	2	1.0	0.025	Unit time X lot size			
Generate Curve 2	N.A.	-	-	-	-	-	-	3	1.0	0.025	Unit time X lot size			
Back up Blanks	N.A.	-	-	-	-	-	-	4	1.0	0.025	Unit time X lot size			
				Time per Block							Time per Block			
Mount Blanks	2	0.25	-	0.08	0.1	0.13	0.2	5	1.0	-	0.08	0.25	0.5	1.0
Generate Block Curve 1	3	1.0	-	0.16	0.25	0.35	0.5	N.A.	-	-	-	-	-	-
Fine Grind Curve 1	4	-	-	0.4	0.5	0.65	1.0	6	-	-	0.4	0.5	0.65	1.0
Finish Polish Curve 1	5	-	-	0.8	1.0	1.3	2.0	7	-	-	0.8	1.0	1.3	2.0
Back up Blanks Curve 2	N.A.	-	-	-	-	-	-	8	1.0	0.25	Unit time X lot size			
Mount Blanks Curve 2	6	0.25	-	0.08	0.1	0.13	0.2	9	1.0	-	0.08	0.25	0.5	1.0
Generate Block Curve 2	7	1.0	-	0.16	0.25	0.35	0.5	N.A.	-	-	-	-	-	-
Fine Grind Curve 2	8	-	-	0.4	0.5	0.65	1.0	10	-	-	0.4	0.5	0.65	1.0
Finish Polish Curve 2	9	-	-	0.8	1.0	1.3	2.0	11	-	-	0.8	1.0	1.3	2.0

CHART III

TOOL DESIGN-MANUFACTURE (COST)

Couplet - 2 Lenses - 4 Radii - 57 Tools

Time in Man Hours

	"Method A"		"Method B"	
	Set up	Operation	Set up	Operation
Prepare Computer input all tools	1.0	-	-	-
Computer run all tools	0.5	-	-	-
Prepare tapes 4 Spot Blocks	4.0	-	-	-
Prepare tapes 4 Grinders	2.0	-	-	-
Prepare tapes 4 Polishers	2.0	-	-	-
Design & Make Dwgs 12 tools	Note 1	-	24.0	-
Turn & Thd. End 57 tools	-	-	2.0	85.5
Face & Bore 57 tools	1.0	28.5	-	-
Assemble Adapter 57 tools	0.5	28.5	-	-
Turn & Face 57 tools	6.5	Note 2	1.0	71.25
Generate 57 tools	Note 2	28.5	6.5	28.5
Mill Spots R_1 (25) 4 tools	1.0	3.3	-	-
Mill Spots R_2 (6) 12 tools	0.5	2.38	-	-
Mill Spots R_3 (7) 17 tools	0.5	2.77	-	-
Mill Spots R_4 (49) 2 tools	0.5	3.37	-	-
Break in Grinders 11 tools	-	44.0	-	44.0
Form Polishers R_1 2 tools	1.0	2.0	1.0	2.0
Form Polishers R_2 6 tools	1.0	6.0	1.0	6.0
Form Polishers R_3 6 tools	1.0	6.0	1.0	6.0
Form Polishers R_4 2 tools	1.0	2.0	1.0	2.0
TOTALS	24	157.32	37.5	245.25

NOTES:

(1) No drawing necessary in Method A

(2) See Note 2, Chart 1

CHART IV
LENS MANUFACTURING (COST)
Couplet (200) - 400 Lenses
Time in Manhours

PROCEDURE	No.	"Method A" Set up	"Method A" Operation	"Method B" Set up	"Method B" Operation
Cut Blanks	400 pcs.	1.0	10.0	1.0	10.0
Generate R_1	200 pcs.	-	-	1.0	5.0
Generate R_2	200 pcs.	-	-	1.0	5.0
Generate R_3	200 pcs.	-	-	1.0	5.0
Generate R_4	200 pcs.	-	-	1.0	5.0
Back up R_1	200 pcs.	-	-	1.0	5.0
Back up R_3	200 pcs.	-	-	1.0	5.0
Mount 25/block R_1	8 blks.	.25	1.04	1.0	4.0
Mount 7/block R_3	29 blks.	.25	3.2	1.0	3.2
Generate Block R_1	8 blks.	1.0	2.8	-	-
Generate Block R_3	29 blks.	1.0	6.4	-	-
Fine Grind Block R_1	8 blks.	-	5.2	-	5.2
Fine Grind Block R_3	29 blks.	-	11.6	-	11.6
Polish Block R_1	8 blks.	-	10.4	-	10.4
Polish Block R_3	29 blks.	-	23.2	-	23.2
Back up R_2	200 pcs.	-	-	1.0	5.0
Back up R_4	200 pcs.	-	-	1.0	5.0
Mount 6/block R_2	34 blks.	.25	2.72	1.0	2.72
Mount 49/block R_4	4 blks.	.25	0.8	1.0	4.00
Generate Block R_2	34 blks.	1.0	5.44	-	-
Generate Block R_4	4 blks.	1.0	2.0	-	-
Fine Grind Block R_2	34 blks.	-	13.6	-	13.6
Fine Grind Block R_4	4 blks.	-	4.0	-	4.0
Polish Block R_2	34 blks.	-	27.2	-	27.2
Polish Block R_4	4 blks.	-	8.0	-	8.0
TOTALS		6.0	137.6	13.0	167.12

RESULTS AND CONCLUSIONS

1. This study has provided basic mathematics and a computer design program for tooling required for lens manufacture using the spot block method. It is intended that the tooling be made on specific N/C equipment. Any 5-axis N/C machine can be used for milling, but its geometric constants must be inserted in the program. The same is true of a programmable lathe.

2. Charts III and IV indicate a savings, for the sample used, of 35% in tool manufacture, and 18% in lens fabrication. This conclusion presupposes a one time high cost of fixturing tools that have universal application, and whose unit cost per lens produced approaches zero as production of lenses increases.

3. The savings cited above will vary with lot sizes tending to increase with an increase in lot size and vice versa. They will also vary from lens to lens, since each lens has its unique set of parameters.

4. Spot blocks can be used only for specific lenses therefore the decision to store or scrap after use has to be made on a projection of future need and the cost of storage balanced against the cost of new tool manufacture if needed. Tool lead time is not a major consideration under Method A.

5. Grinders and polishers can (with small modifications) be used on a variety of lens sizes thereby reducing their unit tool cost. The probability of future use is sufficiently high to justify storage.

6. Tapes generated as a result of the computer design program described in the study should be stored. Having tapes available could reduce production lead time and the cost of storage is relatively small.

7. An APT or UNI-APT N/C tape preparation system can be used to prepare N/C tapes from design parameters developed in STBLK Appendix B.

8. STBLK output is programmable for an automatic drafting machine, if drawings are deemed necessary.

APPENDIX A

MATHEMATICS FOR TOOL DESIGN

I. MATHEMATICAL NOTATION

A. Variables

R_{L1} = Radius of first surface.

R_{L2} = Radius of second surface.

T_A = Axial thickness of lens.

D_L = Finished Diameter of lens.

D_M = Minimum diameter of lens blank.

R_M = Minimum radius of lens blank.

D_B = Actual blank diameter - End Mill Dia.

R_B = Blank radius.

R_{BC} = Blank radius plus clearance.

D_C = Clearance hole diameter. - End Mill Dia.

R_C = Clearance hole radius.

H_1 = Height of first surface on blank.

H_2 = Height of second surface on blank.

H_C = Height of first surface from clearance hole.

T_B = Actual blank thickness.

T_{E1} = Edge thickness with first surface generated.

T_{E2} = Edge thickness with both surfaces generated.

R_{Ei} = Perpendicular distance from center of spot block:
(a) to blank seat (convex)
(b) to top of blank (concave)

R_{Ki} = Spot block spherical radius.

R_{Si} = Clearance radius for concave blocks.

D_{Ai} = Chord across blocked lenses.

D_{AK} = Chord across spot block (Convex)
or
= Aperture of spot block (Concave)

D_{AS} = Chord across spot block (Concave)

H_{Ki} = Height of spot block curve.

H_{Bi} = Spot block overall height.

H_i' = Distance from blank seat to spot block datum.

H_D = See Figure 6.

R_{Gi} = Grinder spherical radius.

D_{AGi} = Chord across grinder (Convex)

D_{AGi} = Aperture of grinder (Concave)

D_{Gi} = Chord across grinder (Concave)

H_{Gi} = Height of grinder curve.

G_{Hi} = Grinder overall height.

R_{Pi} = Polisher spherical radius.

D_{APi} = Chord across polisher (Convex)
or
= Aperture of polisher (Concave)

D_{Pi} = Chord across polisher (Concave)

H_{Pi} = Height of polisher curve.

P_{Hi} = Polisher overall height.

β_j = The angle subtended by a lens on the surface formed by its spherical radius.

ϕ_j = 1/2 the angle subtended by a spot block.

θ_j = Tilt angles.

R_j = Radii perpendicular to spot block axis through intersection of tilt angles at R_{Ei}

α_j = Angular divisions at radii R.

N_j = Whole number of angular divisions.

N_T = Number of spots on block.

ω = Test angle in search routine.

ω' = Test angle in search routine.

X_j = See Figure 8.

Y_j = See Figure 5.

Z_j = See Figures 5 and 8.

NOTE:

Subscript i refers to lens surface number, 1 or 2.

Subscript j refers to number of tilt angle, 1, 2, 3, · · ·

B. Constants

ΔD_L = Factor to set minimum blank size (1.05)

ΔD (R. O.) = Blank round off increment (0.125)

ΔD_B = Clearance used in calculations to prevent spots from overlapping (0.005)

ΔD_C = Difference between spot diameter and clearance hole diameter (0.125)

ΔT_B = Excess thickness in blank (0.010)

ΔR_K = Clearance in concave spot blocks (0. 050)

ϕ_T = Maximum value for ϕ (80°)

R_T = Maximum tool radius.

H_{DT} = Minimum for H_D (0. 250)

ΔR_p = Difference between grinder and polisher radii (0. 200)

ΔD_T = Factor to determine concave tool O. D. (1. 1)

Figure 8	L_1	= Machine spindle extension	= 6. 000
	L_2	= Tool holder extension	= 5. 000
	L_3	= End mill extension	= 3. 000
	W_1	= Spindle radius	= 2. 875
	W_2	= Tool holder radius	= 2. 000

Figure 6	C_1	= Distance from ℄ of rotary table to pivot point	= 3. 3465
	C_2	= Distance from pivot point to top of table	= 3. 8386
	C_3	= Distance from pivot point to machine table top	= 4. 7236
	C_4	= Distance from Rotary Table Top to Datum	= 3

Figure 9	C_5	= Distance from Div. Hd Pivot Pt. to Datum	= 6. 3125
	C_6	= Distance from Div. Hd Pivot Pt. to Table	= 4. 6875
	C_7	= Distance from Div. Hd Pivot Pt. to axis of Hd.	= . 375

II. MATHEMATICS

SIGN CONVENTIONS

Convex Lens = (+) R_L

Concave Lens = (-) R_L

Plano Lens (+) R_L = 10,000

GEOMETRIC PRIORITIES (Figure 12)

Case 1. Convex - Convex

R_{L1} = Longest Radius

R_{L2} = Shortest Radius

Case 2. Convex - Concave

R_{L1} = Convex Radius

R_{L2} = Concave Radius

Case 3. Concave - Concave

R_{L1} = Longest Radius

R_{L2} = Shortest Radius

Case 4. Plano - Convex

R_{L1} = Plano

R_{L2} = Convex Radius

Case 5. Plano - Concave

R_{L1} = Plano (No tools designed for plano surfaces.)

R_{L2} = Concave Radius

Note: In all subsequent calculations, when an either/or occurs, go to the next step or to the instruction; as dictated by the results.

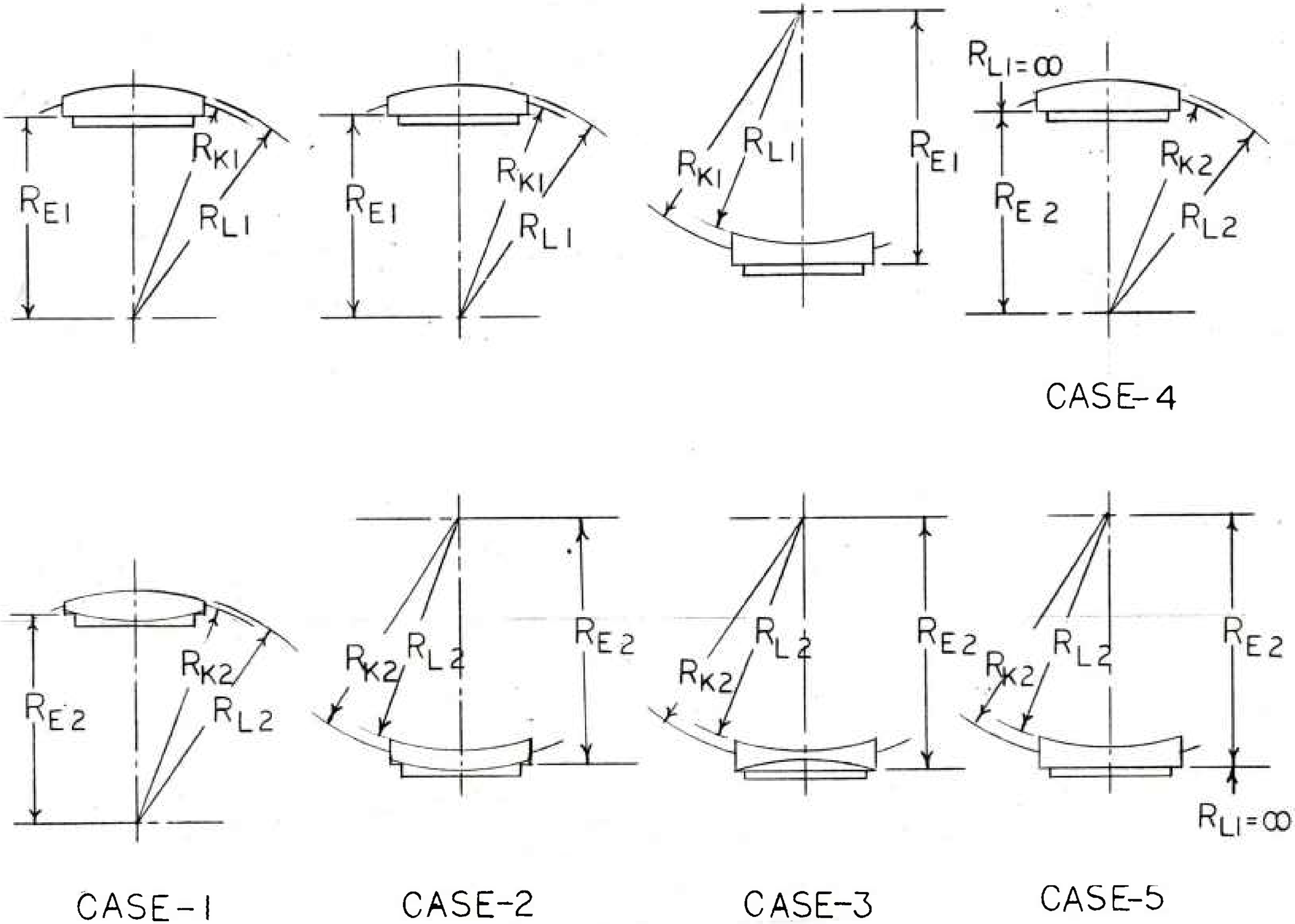


Figure 12. Geometric Priorities (Computer Selected)

START ALL CASES:

$$D_M = (\Delta D_L)\ D_L$$

$$R_M = \frac{D_M}{2}$$

$D_B = D_M$ Rounded off upwards to nearest 1/8 inch. Blank dia.

$$R_B = \frac{D_B}{2}$$

$$R_{BC} = \frac{D_B + \Delta D_B}{2}$$

$$D_C = D_B - \Delta D_C$$

$$R_C = \frac{D_C}{2}$$

Go to para 1, 2, 3, 4 or 5 as determined by Geometric Priorities.

1. Convex - Convex

$$H_1 = R_{L1} - \sqrt{R_{L1}^2 - R_B^2}$$

$$H_2 = R_{L2} - \sqrt{R_{L2}^2 - R_B^2}$$

$T_B = T_A + \Delta T_B$ = Blank Thk.

$$T_{E1} = T_B - H_1$$

Go to 2A

2. Convex - Concave

$$H_1 = R_{L1} - \sqrt{R_{L1}^2 - R_B^2}$$

$$H_2 = \left|R_{L2}\right| - \sqrt{R_{L2}^2 - R_B^2}$$

$T_B = T_A + H_2 + \Delta T_B$ = Blank thk.

$$T_{E1} = T_B - H_1$$

2A. First Curve Convex

$$H_C = R_{L1} - \sqrt{R_{L1}^2 - R_C^2}$$

$$R_{E1} = R_{L1} - \left(T_B - \frac{\Delta T_B}{2}\right)$$

$$R_{K1} = \sqrt{\left(R_{E1} + \frac{T_{E1}}{2}\right)^2 + R_B^2}$$

Second Curve Convex Go to 6

Second Curve Concave set H = 0, and go to 7

3. Concave - Concave

$$H_1 = \left|R_{L1}\right| - \sqrt{R_{L1}^2 - R_M^2}$$

$$H_2 = \left|R_{L2}\right| - \sqrt{R^2_{L2} - R_M^2}$$

$$H_C = 0$$

$$T_B = T_A + H_1 + H_2 + \Delta T_B = \text{Blank thk.}$$

$$T_{E1} = T_B - 0.005$$

$$R_{E1} = \left|R_{L1}\right| + T_A + H_2 + \frac{T_B}{2}$$

$$R_{K1} = \sqrt{\left(R_{E1} - \frac{T_{E1}}{2}\right)^2 + R^2_B}$$

$$R_{S1} = \sqrt{\left(R_{E1} - \Delta R_K\right)^2 + R^2_B}$$

Go to 7

4. Plano - Convex

$$H_1 = 0$$

$$H_2 = R_{L2} - \sqrt{R_{L2}^2 - R_B^2}$$

$$H_C = 0$$

$$T_B = T_A + \Delta T_B$$

Go to 6

5. Plano - Concave

$$H_1 = 0$$

$$H_2 = \left|R_{L2}\right| - \sqrt{R_{L2}^2 - R_B^2}$$

$$H_C = 0$$

$$T_B = T_A + H_2 + \Delta T_B$$

$$T_{E1} = T_B - \frac{\Delta T_B}{2}.$$

6. Curve 2 Convex

$$T_{E2} = T_A - H_1 - H_2$$

$$R_{E1} = R_{L2} - T_A + H_C$$

$$R_{K2} = \sqrt{\left(R_{L2} - \frac{T_{E2}}{2}\right)^2 + R_B^2}$$

Go to 8A

7. Curve 2 - Concave

$$T_{E2} = T_{E1}$$

$$R_{E2} = |R_{L2}| + T_A + H_1 - H_C$$

$$R_{K2} = \sqrt{\left(|R_{L2}| + \frac{T_{E2}}{2}\right)^2 + R_B^{\,2}}$$

R_{L1} Convex Go to 8A

R_{L1} Concave Go to 8B I or II

8A. R_{L1} Convex

$$\phi_{TST} = 80^\circ$$

$$R_{Ai} = R_{Li} \text{ Sin } 80^\circ$$

$$0 < R_{Ai} - 5 \leq 0 \quad \text{then} \quad \phi = 80^\circ$$

$$\phi = \text{Sin} - 1 \frac{5}{R_{Li}}$$

$$R_{Ai} = R_{Li} \text{ Sin } \phi$$

$$H_{Li} = R_{Li} - \sqrt{R_{Li}^{\,2} - R_{Ai}^{\,2}}$$

$$R_{AKi} = R_{Ki} \text{ Sin } \phi$$

$$D_{AKi} = 2\,R_{AKi} \quad \text{Spot block Dia.}$$

$$H_{Ki} = R_{Ki} - \sqrt{R_{Ki}^{\,2} - R_{AKi}^{\,2}} \quad \text{Spot block ht.}$$

$$H'_{TST} = H_{Ki} - (R_{Ki} - R_{Ei}) + H_{DT} + H_C$$

$0 \leq H'_{TST} - (1 + H_C) < 0$

$H' = H'_{TST}$ (Spot block fig. 5)

and

$H_D = H_{DT}$ (Spot block fig. 5)

$H' = 1 + H_C$ (Spot block fig. 5)

and

$H_D = H' - H_{Ki} + (R_{Ki} - R_{Ei})$ (Spot block fig. 5)

$H_{Bi} = H_{Ki} + H_D$ Spot Block Ht.

$R_{Gi} = R_{Li}$ Grinder sph. rad. (Concave)

$D_{AGi} = 2\,R_{Ai}$ Grinder Aperture

$D_{Gi} = 1.1\,D_{AGi}$ Grinder O. D.

$$H_{Gi} = |R_{Gi}| - \sqrt{R_{Gi}^{2} - R_{AGi}^{2}}$$

$G_{Hi} = H_{Gi} + 1.00$ Grinder Ht.

$R_{Pi} = R_{Gi} - 0.200$ Spherical radius polisher (Concave)

$R_{APi} = |R_{Pi}| \sin \phi$

$D_{APi} = 2\,R_{APi}$ Polisher Aperture

$D_{Pi} = 1.1\,D_{APi}$ Polisher O. D.

$$H_{Pi} = |R_{Pi}| - \sqrt{R_{Pi}^{2} - R_{APi}^{2}}$$

$P_{Hi} = H_{Pi} + 1.000$ Polisher Ht.

$$\frac{\beta}{2} = \tan^{-1} \frac{R_{BC}}{R_{Ei}}$$, Round off upward to nearest 1/2 degree

$$\beta = 2\,\frac{\beta}{2}$$, R. O.

Go to 9

8B. R_{Li} Concave

I Search Routine - CIM-X (Figure 7)

1	$0 \leq R_{Ei} - L_2 < 0$	Go to 6
2	$R_{A1} = R_{L1} \text{ Sin } 80°$	
3	$0 \leq (R_{A1} - 5) < 0$	Go to 5
4	$\phi = \text{Sin}^{-1} \dfrac{5}{R_{L1}}$	Go to para 8B III
5	$\phi = 80°$	Go to para 8B III
6	$0 \leq (R_{Ei} - L_3) < 0$	Go to 12
7	$\omega = \text{Cos}^{-1} \dfrac{W_1}{R_{Ki}}$	
8	$\omega' = \text{Sin}^{-1} \dfrac{L_2 - R_{Ei}}{R_{Si}}$	
9	$0 \leq (\omega - \omega') < 0$	Go to 11
10	$\phi = \dfrac{\beta/2 + 90 + \omega}{2}$	Go to para 8B III
11	$\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$	Go to para 8B III
12	$R_S \leq (L_2 - R_{Ei}) < R_S$	Go to 20
13	$R_S \leq (L_3 - R_{Ei}) < R_S$	Go to 15
14	$\phi = 80°$	Go to para 8B III
15	$\omega = 70 - \beta/2$	
16	$\omega' = \text{Sin}^{-1} \dfrac{L_3 - R_{Ei}}{R_S}$	
17	$0 \leq (\omega - \omega') < 0$	Go to 19

18 $\phi = \beta/2 + 90 + \omega'$ Go to 8B III

19 $\phi = 80°$ Go to 8B III

20 $\omega = \text{Cos}^{-1} \dfrac{W_2}{R_K}$

21 $\omega' = \text{Sin}^{-1} \dfrac{L_3 - R_{Ei}}{R_{Si}}$

22 $0 \leq (\omega - \omega') < 0$ Go to 24

23 $\phi = \dfrac{\beta/2 + 90 + \omega}{2}$ Go to 8B III

24 $\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$ Go to 8B III

II Search Routine K & T (Figure 7)

1 $0 \leq (R_{E1} - L_1) < 0$ Go to 7

2 $$\phi_T = \frac{\text{Cos}^{-1}\left(\dfrac{R_{Ki} - L_1}{R_{Ki}}\right) + \dfrac{\beta}{2}}{2}$$

3 $R_{AI} = R_{L1} \text{ Sin } \phi_T$

4 $0 \leq (R_{Ai} - 5) < 0$ Go to 6

5 $\phi = \text{Sin}^{-1} \dfrac{5}{R_{Li}}$ Go to para 8B III

6 $\phi = \phi_T$ Go to para 8B III

7 $0 \leq (R_{E1} - L_2) < 0$ Go to 14

8 $\omega = \text{Sin}^{-1} \dfrac{L_1 - R_{Ei}}{R_{si}}$

9 $\phi_T = \dfrac{\beta/2 + 90 + \omega}{2}$

10 $R_{Ai} = R_{Li} \text{ Sin } \phi_T$

11 $0 \leq R_{Ai} - 5 < 0$ Go to 13

12 $\phi = \text{Sin}^{-1} \dfrac{5}{R_{Li}}$ Go to para 8B III

13 $\phi = \phi_T$ Go to para 8B III

14 $0 \leq (R_{Ei} - L_3) < 0$ Go to 29

15 $R_s \leq (L_1 - R_{Ei}) < R_{Si}$ Go to 21

16 $\omega = \text{Cos}^{-1} \dfrac{W_2}{R_{Ki}}$

17 $\omega' = \text{Sin}^{-1} \dfrac{L_2 - R_{Ei}}{R_{Si}}$

18 $0 \leq (\omega - \omega') < 0$ Go to 20

19 $\phi = \dfrac{\beta/2 + 90 + \omega}{2}$ Go to para 8B III

20 $\phi = \dfrac{\beta/2 + 90 + \omega}{2}$ Go to para 8B III

21 $\omega = \text{Cos}^{-1} \dfrac{W_1}{R_{K1}}$

22 $\omega = \text{Sin}^{-1} \dfrac{L_1 - R_{Ei}}{R_{Si}}$

23 $0 \leq (\omega - \omega') < 0$ Go to 25

24 $\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$ Go to para 8B III

25 $\omega' = \text{Sin}^{-1} \dfrac{L_2 - R_{Ei}}{R_{Si}}$

26 $0 \leq (\omega - \omega \;\;) < 0$ Go to 28

27 $\phi = \dfrac{\beta/2 + 90 + \omega}{2}$ Go to para 8B III

28 $\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$ Go to para 8B III

29 $R_{Si} \leq (L_2 - R_{Ei}) < R_{Si}$ Go to 37

30 $R_{Si} \leq (L_3 - R_{Ei}) < R_{Si}$ Go to 32

31 $\phi = 80^\circ$ Go to para 8B III

32 $\omega = 70 - \beta/2$

33 $\omega' = \mathrm{Sin}^{-1} \dfrac{L_3 - R_{Ei}}{R_{Si}}$

34 $0 \leq (\omega - \omega') < 0$ Go to 36

35 $\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$ Go to para 8B III

36 $\phi = 80^\circ$ Go to para 8B III

37 $\omega = \mathrm{Cos}^{-1} \dfrac{W_2}{R_{Ki}}$

38 $\omega' = \mathrm{Sin}^{-1} \dfrac{L_3 - R_{Ei}}{R_{Si}}$

39 $0 \leq (\omega - \omega') < 0$ Go to 41

40 $\phi = \dfrac{\beta/2 + 90 + \omega}{2}$ Go to para 8B III

41 $\phi = \dfrac{\beta/2 + 90 + \omega'}{2}$ Go to para 8B III

$H' = 1 + H_C$

$R_{AKi} = R_{Ki} \ \text{Sin}\ \phi$

$D_{AKi} = 2\,R_{AKi}$ = Spot Block Aperture

$H_{Ki} = R_{Ki} - R_{Ki}^{\ 2} - R_{AKi}^{\ 2}$

$H_{Bi} = H_i' + R_{Ei} - R_{Ki} + H_{Ki}$ = Spot Block Ht.

Mult. R_{Ki} by (-1) = Spot Block Sph. Rad.

$R_{AS} = R_{Si} \ \text{Sin}\ \phi$

$D_{AS} = 2\,R_{AS}$ = Spot Block O. D.

$R_{Gi} = R_{Li}$ = Grinder Sph. Rad

$R_{AGi} = R_{Gi} \ \text{Sin}\ 0$

$D_{AGi} = 2\,R_{AGi}$ = Grinder O. D.

$H_{Gi} = R_{Gi} - \sqrt{R_{Gi}^{\ 2} - R_{AGi}^{\ 2}}$

$0 \leq H_i' - H_{Gi} < 0$

$G_{Hi} = H_i'$ = Grinder Ht.

$G_{Hi} = H_{Gi}$ = Grinder Ht.

$R_{Pi} = R_{Gi} - 0.200$ = Polisher Sph. Rad.

$R_{APi} = R_{Pi} \ \text{Sin}\ 0$

$D_{APi} = 2\,R_{APi}$ = Polisher Dia.

$$H_{Pi} = R_{Pi} - \sqrt{R_{Pi}^2 - R_{Pi}^2}$$

$0 \leq H'_i - H_{Pi} < 0$

$P_{Hi} = H'_i$ Polisher Ht.

$P_{Hi} = H'_i$ Polisher Ht.

$\frac{\beta}{2} = \text{Sin}^{-1} \frac{R_{BC}}{R_{Li}}$, Round off to nearest 1/2 degree

$\beta = 2 \frac{\beta}{2}$ R. O.

Go to 9

9. Calculate θ_j, $_j = 1, 2, 3, \ldots$

$\theta = \phi - \frac{\beta}{2}$, where $_j = 1$

$0_j < 0$ Error stop

Start loop

$0 \leq (\theta_j - \frac{\beta}{2}) < 0$, $\theta_j = 0$

$0 \leq (\theta_j - \beta) < 0$

Tilt $<$ $= 90 - \theta$

$\theta_j + 1 = \theta_j - \beta$

Tilt $<$ $= 90 - 0$ Center Lens

Tilt $<$ $= 90 - \theta$ No Center Lens

End of loop

If R_{Li} convex Go to 10

If R_{Li} concave Go to 11

10 R_{Li} Convex

$$R_j = R_{Ei} \text{ Sin } \theta_j$$

$$R_{j+1} = R_{Ei} \text{ Sin } \theta_{j+1}$$

Continue for all values of θ_j and go to 12

11 R_{Li} Concave

$$R_j = (|R_{Li}| - H_i) \text{ Sin } \theta_j$$

Continue for all values of θ_j and go to 12

12 Calculate no. of spot on block

$$\frac{\alpha_j}{2} = \text{Sin}^{-1} \frac{R_{BC}}{R_j}$$

$$\alpha_j = 2 \text{ Sin}^{-1} \frac{R_{BC}}{R_j}$$

$$N_j = \frac{360}{\alpha_j} \quad \text{Round off down to nearest integer}$$

$$\alpha_j = \frac{360}{N_j} \quad \text{(R.O.)}$$

$$\frac{\alpha_{j+1}}{2} = \text{Sin-}^{1} \frac{R_{BC}}{R_j + 1}$$

$$\alpha_{j+1} = 2 \text{ Sin}^{-1} \frac{R_{BC}}{R_j + 1}$$

Continue for all values of R_j

$$N_T = \sum N_j$$

Go to coord. (Convex Concave) CIM-X

or

Go to (Convex Concave) K and T

13a. Calc. Coordinates CIM-X

Convex Block (Fig. 6)

$S_i = H' + C_4$

$K_i = S_i - R_{Ei}$

Concave Block (Fig. 7)

$K_i = R_{Ei} + H_i' + C_4$

Change Sign of R_{Ei}

All Blocks

$Y_j = C_3 + C_2 \text{ Sin } \theta_j + C_1 \text{ Cos } \theta_j + K_i \text{ Sin } \theta_j$

$Y_j = (C_2 + K_i) \text{ Sin } \theta_j + C_1 \text{ Cos } \theta_j + C_3$

$Z_j = C_1 + C_2 \text{ Cos } \theta_j - C_1 \text{ Sin } \theta_j + K_i \text{ Cos } \theta_j + R_{Ei}$

$\Delta Z = H_{Ci} + .030$

13b. Calc. Coordinates K and T

Convex Block (Fig. 8A)

$S = H' + C_5$

$K_i = S - R_{Ei}$

Concave Block (Fig. 8B)

$K_i = R_{Ei} + H_i' + C_5$

Change sign of R_{Ei} from (+) to (-)

All Blocks

$$X_j = K_i \text{ Sin } \theta_j + C_7 - C_7 \text{ Cos } \theta_j$$

$$X_j = K_i \text{ Sin } \theta_j + C_7 \ (1 - \text{Cos } \theta_j)$$

$$Z_j = K_i \text{ Cos } \theta_j + C_7 \text{ Sin } \theta_j + R_{Ei} + C_6$$

$$\Delta Z = H_C + 0.030$$

APPENDIX B

COMPUTER PROGRAM - STPBLK

INPUT, DATA
One Card Per Lens

Columns (1 - 9), Lens Radius

Columns (10-18), Lens Radius

Columns (19-27), Axial Thickness

Columns (28-36), Lens Diameter

Column 73, Indicator for Machine Geometry

1 - K and T Dividing Head

2 - Cim-X N/C

NOTE:

(+) Sign indicates Convex Lens

(-) Sign indicates Concave Lens

Radius of 10,000 indicates Plano

```
              PROGRAM STPBLK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C-            PROGRAM STPBLK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C-            CALCULATION FOR SPOT BLOCKS, BOTH RADIUS .LE. 5.00 AND RAD. .GT. 5.00
C-                                       BOTH CONVEX AND CONCAVE LENSES
              DIMENSION  A(8), REFF(2), RTST(2), IND(2), RB(2)
              DIMENSION  RBLOK(2), EFTHK(2), DEY(2)
              EQUIVALENCE  (RBLOK1,RB(1) ), (RBLOK2,RB(2) )
C-              * - * - * - * - * - * - * - * - *
C-              SAMPLE INPUT DATA CARD
C-   IN CARD COLUMN-
C-1       9/10      18/19     27/28     36/37                                73
C-- RL1     RL2         THK.       DIAM.                                       INDICATOR
C-        1   IS FOR THE K + T INDEXING HEAD     (IN CC. 73)
C-        2   IS FOR THE CIM-X N.C. MILLING MACHINE     (IN CC. 73)
C-              * - * - * - * - * - * - * - * - *
              DATA NREAD,NPRINT/5,6/
C-             RTOD = RADIANS TO DEGREES CONVERSION FACTOR
              DATA RTOD, PI/57.29578, 3.14159265/
C-              THE FOLLOWING IS THE DELTA Z FOR BOTH CASES (OLD AND NEW)
              DATA  DELY, DELZ/2*0.0300/
C-             TOLMR IS THE MAXIMUM RADIUS OF THE TOOL                           R.GT.5.0
              DATA TOLMR/5.00/                                                   R.GT.5.0
              DATA  RF/6.31250/
C-            HPIVOT IS THE VERTICAL DISTANCE  (ON INDEXING HEAD) BETWEEN WORK
C-                           PIECE AND PIVOT POINT OF THE  INDEXING HEAD OR PLATE
              DATA  HPIVOT/4.6875/                                               *******
C-            AXDIS IS THE AXIAL DISPLACEMENT OF THE INDEXING HEAD (TOWARD THE SIDE)
              DATA  AXDIS/0.3750/
              DATA DSUBP /5.000/
C-             VALUES FOR THE CIM-X N.C. MACHINE
              DATA  DSTT, DEHT, HC/3.34645, 3.83858, 4.72360/
C-            CLR  IS THE AXIAL THICKNESS TOLERANCE ALLOWANCE    (WHEN  TSB IS CALCULATED
              DATA  CLR/0.0100/
              DATA  W1, W2, W3/2.8750, 2.000,0.010/
              DATA  ELL1, ELL2, ELL3/6.000, 5.000, 3.000/
C-            PLANO IS SET AT 10,000.0 FOR FLAT SURFACES
              DATA  PLANO/10000.0/
            3 FORMAT (6F9.4, 2F9.5, I1)
            4 FORMAT (14X, I3, 19H LENS ON BLOCK NO. , I2 /  )
            5 FORMAT (14H1 INPUT DATA =, 4X, 4F11.4, 10X, I2/ 5X, 16HLENS BLANK DATA
             1DATA / 10X, 17HBLANK DIAMETER = , F9.4/ 10X, 18HBLANK THICKNESS =  ,
             2 , F9.4 )
           10 FORMAT (4X, 32H CALCULATIONS FOR SPOT BLOCK NO. , I2/ 10X, 19HSPHERICAL
             2RICAL RADIUS, C,I1,2H =, F9.4/ 10X, 27HSPHERICAL RADIUS OF BLOCK = ,
             3 , F9.4     )
           25 FORMAT (10X, 16HBLOCK DIAMETER = , F9.4 / 10X, 14HBLOCK HEIGHT = ,
             1 F9.4 )
           26 FORMAT (1H0 , 10X, 8HSIDE NO. , I2, 9H IS PLANO  /// )
           27 FORMAT (10X, 26HBLOCK APERTURE (CONCAVE) = , F9.4/ 10X, 23HBLOCK O.D.
             1.D. (CONCAVE) = , F9.4/ 10X, 14HBLOCK HEIGHT = , F9.4, 5H (H1)  )
           29 FORMAT (10X, 27HDIAMETER OF HOLES (SPOTS) = , F9.4/ 10X, 29HDIAMETER
             1ER OF CLEARANCE HOLES = , F9.4/ 10X, 19HEFFECTIVE RADIUS = , F9.4 / 10X,
             2/ 10X, 6H PHI = , F7.2   / 10X, 7H BETA = , F6.2 )
```

```
   32 FORMAT (11X, I2, 3X, F9.4, 4X, I3, 4X, F9.4, 3X, F9.4, 2(2X,F9.4))
   34 FORMAT (10X, 4HRING, 5X, 4HTILT, 5X, 5HNO.OF, 4X, 9HPOSITION , 10X,
     1,19HK + T INDEXING HEAD / 11X, 3HNO., 5X, 5HANGLE, 4X, 5HSPOTS ,
     2 5X, 5HANGLE, 9X, 2H X, 8X, 2H Z, 9X, 7HDELTA Z ,  /    )
   36 FORMAT (19H      GRINDER DATA- / 10X, 18HSPHERICAL RADIUS = , F9.4,
     1/ 10X, 18HGRINDER DIAMETER = , F9.4/ 10X, 16HGRINDER HEIGHT = , F9.4 )
     2.4  )
   37 FORMAT (21H      POLISHER DATA-  / 10X, 18HSPHERICAL RADIUS = , F9.4 /
     1.4 / 10X, 19HPOLISHER DIAMETER = , F9.4 /  10X, 17HPOLISHER HEIGHT = ,
     2 =  ,  F9.4  /  )
   54 FORMAT (10X, 4HRING, 5X, 4HTILT, 5X, 5HNO.OF, 4X, 9HPOSITION , 10X,
     1 , 21HCIM-X N.C. EQUIPMENT / 11X, 3HNO., 5X, 5HANGLE, 4X, 5HSPOTS,*5X,
     2 5X, 5HANGLE, 9X, 2H Y, 8X, 2H Z, 9X, 7HDELTA Z     /       )
  136 FORMAT (19H      GRINDER DATA-  /  10X, 18HSPHERICAL RADIUS = , F9.4 /
     1.4 /10X, 29HGRINDER APERTURE (CONCAVE) =   ,  F9.4/10X, 14HGRINDER O.D.
     20.D. = , F9.4/ 10X, 16HGRINDER HEIGHT =    , F9.4 )
  137 FORMAT (21H      POLISHER DATA-  / 10X, 18HSPHERICAL RADIUS = , F9.4 /
     1.4 / 10X, 30HPOLISHER APERTURE (CONCAVE) = , F9.4/ 10X, 15HPOLISHER O.D.
     2R O.D. = , F9.4/ 10X, 17HPOLISHER HEIGHT = , F9.4    /     )
  167 FORMAT (1H  , 10X, 16H NO CENTER LENS    )
  188 FORMAT (18H  *SPECIAL CASE*     )
      TT = TOLMR * 2.00
C-    A(1)  OR  A(2)   CONTAINS  RL1 AND RL2                        R.GT.5.0
C-   A(3) = AXIAL THICKNESS                A(4) = DIAMETER OF LENS
    1 READ (NREAD,3)  (A(I), I = 1, 8), LIMP
C     LAST DATA CARD HAS ALL ZEROS
      IF (A(3) .LE. 0.000)  STOP
C     MAKE R1=LONGEST RADIUS, CALCULATE FOR R1 FIRST
C-    SELECT CONCAVE OR CONVEX SIDES OF LENS AND CLASIFY THE LENS
      NOLT = 0
      IND(1) = 1
      IND(2) = 1
      AA1  = ABS(A(1) )
      AA2  = ABS(A(2) )
      IF (A(1) .GT. 0.010 .AND.  A(2) .GT. 0.010)  NOLT = 11
      IF (A(1) . LT. 0.000  .OR. A(2) .LT. 0.000)  NOLT = 12
      IF (A(1) .LT. 0.000  .AND.  A(2) .LT. 0.000)  NOLT = 22
      IF (NOLT .GT. 10)  GO TO 6
      A(7) = AMIN1(AA1,AA2)  +  0.008
      A(8)  =  AMIN1(A(1), A(2) )
      NOLT  =  92
      IF (A(7) .GT. AA1)  AA1 = PLANO
      IF (A(7) .GT. AA2)  AA2 = PLANO
      RTST(1) =  PLANO
      RTST(2) = AMIN1(AA1,AA2)
      AA1 = PLANO
      AA2 = RTST(2)
      A(1) = PLANO
      A(2)  =  A(8)
      IF (A(8) .LT. 0.000)   GO TO 6
      NOLT = 91
      A(2) = RTST(2)
C-    THE FOLLOWING TESTS ESTABLISHES THE PRIORITY OF WHICH SIDE OF THE LENS TO
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C-          DO FIRST.
          6 IF (NOLT .NE. 11)  GO TO 7
C-          DOUBLE CONVEX LENS
            RTST(1) = AMAX1(AA1,AA2)
            RTST(2) = AMIN1(AA1,AA2)
            IF (RTST(1) .GT. 9999.8)  NOLT = 91
            A(1)  =  RTST(1)
            A(2)  =  RTST(2)
          7 IF (NOLT .NE. 22)  GO TO 8
C-          DOUBLE CONCAVE LENS
            RTST(1) = AMAX1(AA1,AA2)
            RTST(2) = AMIN1(AA1,AA2)
            IND(1) = 2
            IND(2) = 2
            IF (RTST(1) .GT. 9999.8)  NOLT = 92
            A(1) = -1.0 * RTST(1)
            A(2) = -1.0 * RTST(2)
          8 IF (NOLT .NE. 12)  GO TO 9
C-          CONVEX-CONCAVE LENS
            RTST(1) =  AMAX1(A(1),A(2) )
            RTST(2) = AMIN1(A(1),A(2) )
C-          R-1 IS THE CONVEX  AND  R-2 IS THE CONCAVE SIDE
            A(1)  =  RTST(1)
            A(2)  =  RTST(2)
            RTST(2) = ABS(A(2) )
            IND(2) = 2
            IF (RTST(1) .GT. 9999.8)  NOLT = 92
C-          PLANO-CONVEX IS NOLT = 91
          9 IF (NOLT .GE. 90)  RTST(2) = AMIN1(AA1,AA2)
C-          PLANO-CONCAVE IS NOLT = 92
            IF (NOLT .NE. 92)  GO TO 11
            IND(2) = 2
         11 CONTINUE
            IF (A(1) .LT. 0.000)  IND(1) =  2
            IF (A(2) .LT. 0.000)  IND(2) =  2
            R1 = RTST(1)
            R2 = RTST(2)
            DEY(1)  =  DELY
             DEY(2) = 0.000
            DBLMIN  =  A(4) * 1.0500
            RMM = DBLMIN / 2.000
            IDB = IFIX(DBLMIN)
            DPART=DBLMIN-FLOAT(IDB)
C-         THE FOLLOWING ROUNDS BLANK DIAMETER UPWARDS TO THE NEAREST EIGHTH (1/8)
            AN8TH = 0.1250
         15 IF(AN8TH.GE.DPART) GO TO 20
            AN8TH = AN8TH + 0.1250
            GO TO 15
         20 DBLANK = FLOAT(IDB) + AN8TH
            RBLANK = DBLANK / 2.000
              RBC  = (DBLANK +0.005) / 2.000
C           DPRING=DIAMETER OF POSITION RING
            DPRING = DBLANK - 0.1250
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      RPRING=DPRING/2.0
      H1 = R1 - SQRT(R1**2 - RBLANK**2)
      IF (IND(1) .EQ. 1)  DEY(2) = H1
       H2  =  R2 - SQRT(R2**2 - RBLANK**2)
      TSB  =  A(3) + CLR
      IF (NOLT .EQ. 12)   TSB = TSB + H2
      HCLR = R1 - SQRT(R1**2 - RPRING**2)
      EFTHK(1) = A(3) - H1
      REFF(1) = R1 - TSB + 0.0050
      RBLOK1 = SQRT ( ( REFF(1) + EFTHK(1) /2.0)**2 + RBLANK**2)
      IF (NOLT .NE. 22)   GO TO 22
      H1 = R1 - SQRT(R1**2 - RMM**2)
      H2  =  R2 - SQRT(R2**2 - RMM**2)
      TSB = TSB + H1 + H2
      HCLR = 0.000
      EFTHK(1)  =  TSB - 0.0050
      REFF(1) = R1 + A(3) + 0.0050 + H2
      RBLOK1 = -1.00 * SQRT((REFF(1) - EFTHK(1)/2.00)**2 + RBLANK**2)
      RS1  =  SQRT( (REFF(1) + 0.050)**2 + RBLANK**2)
   22    CONTINUE
      WRITE (NPRINT,5)   A(1), A(2), A(3), A(4), LIMP, DBLANK, TSB
C-     THE FOLLOWING IS CORRECTION FOR PLANO-XXX  LENS
      IF (NOLT .GT. 90)   H1 = 0.000
      IF (NOLT .GT. 90)   HCLR = 0.000
      IF (NOLT .GT. 90)  H2 = R2 - SQRT(R2**2 - RBLANK**2)
      IF (NOLT .EQ. 92)  TSB = A(3) + H2 + CLR
      IF (NOLT .EQ. 92)  EFTHK(1) = TSB - 0.0050
      RBLOK(1)  =  ABS(RBLOK1)
      EFTHK(2) = A(3) - H1 - H2
      IF (IND(2) .EQ. 2)  EFTHK(2) = EFTHK(1)
      REFF(2) = R2 - A(3) + HCLR - 0.0050
      IF (IND(2) .EQ. 2)   REFF(2) = R2 + A(3) + H1 - HCLR
C-    RBLOK2 = SQRT( (R2 - EFTHK(2)/2. )**2 + RBLANK**2)
      RBLOK2 = SQRT( (R2 - HLENS - EFTHK(2)/2.0)**2 + RBLANK**2)
      IF (IND(2) .EQ. 2)    RBLOK2 = R2 + EFTHK(2)/2.00                NEW
C-     RSS2  =  SQRT( (REFF(2) + RBLOK2) ** 2 + RBLANK ** 2 )
      RBLOK(2) = RBLOK2
C     THE FOLLOWING LOOP CALCULATES BLOCK FOR R1,THEN RETURNS FOR R2.
      DO 60  K = 1, 2
C-    INITIALIZE THE LENS PER BLOCK COUNT (LPB)
       LPB = 0
      IF (RTST(K) .LT.  9999.8)   GO TO 47
      WRITE (NPRINT,26)  K
         GO  TO  60
   47 CONTINUE
      RLDUM = RTST(K)
      KSIDE = K
      IF (IND(K) .EQ. 2)  RLDUM = -1.0 * RTST(K)
      WRITE (NPRINT,10)  K. KSIDE, RLDUM, RB(K)
C-     THE FOLLOWING IS THE CONVERSION FROM RADIANS TO DEGREES
      HBETA = RTOD * ATAN(RBC/REFF(K) )
      IF(IND(K) .EQ. 2)  HBETA = ASIN(RBC/RTST(K) ) * RTOD            CONCAVE
C-    BETA  IS THE ANGLE SUBTENDED BY A LENS ON THE SPOT BLOCK
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      BETA = (HBETA + 0.5000) * 4.00
      KDUM = IFIX(BETA) / 2
      BETA  = FLOAT(KDUM)
      HBETA  =  BETA * 0.500
C-     THE FOLLOWING ROUTINE IS ONLY USED WITH CONCAVE LENS, -- WHERE A
C-                   DIFFERENT ANGLE (PHI)  IS NEEDED DUE TO INTEREFERENCE
C-     CHI (PHI) IS ONE HALF  (1/2) THE TOTAL ANGLE OF THE SPOT BLOCK
      CHI = 80.00
      CHIRAD = 80.0 / RTOD
      RADUM = RTST(K)  *  SIN(CHI/RTOD)
      IF (RADUM .LT. TOLMR) GO TO 33
      CHI = ASIN (TOLMR/RTST(K) ) * RTOD
      IF (IND(K) .EQ. 2)   CHI = CHI - 0.5000
      ICHI = CHI
      XDUM = CHI - FLOAT(ICHI)
      CHI = FLOAT(ICHI)
      IF (XDUM .GE. 0.5000)  CHI = CHI + 0.5000
      CHIRAD = CHI / RTOD
      RADUM = RTST(K) * SIN(CHIRAD)
   33    CONTINUE
      RASP = RBLOK(K) * SIN(CHIRAD)
      DASP = RASP * 2.00
      RGRIND = -1.00 * RLDUM
      HGRIND = RTST(K) - SQRT(RGRIND ** 2 - RADUM ** 2) + 1.00
      POLR = -1.00 * (RTST(K) + 0.1500)
      IF (IND(K) .EQ. 2)   POLR = RTST(K) - 0.1500
      DPOL = ABS(POLR * SIN(CHIRAD) )
      HTPOL = ABS(POLR) - SQRT(POLR ** 2 - DPOL ** 2) + 1.00
      IF (IND(K) .NE. 2)  GO TO 63
      HGRIND = ABS(RGRIND) - SQRT(RGRIND**2 - RADUM**2)
C-                 WHERE  H-PRIME = 1. + H-SUB-C
         HPRIME = HCLR + 1.000
      IF (HGRIND .LE. HPRIME)  HGRIND = HPRIME
      HTPOL = HTPOL - 1.000
      IF (HTPOL .LE. HPRIME)  HTPOL = HPRIME
   63 CONTINUE
                 DPOL = DPOL * 2.0000
       X2N = CHI * 2.0 / BETA
      I2N=IFIX(X2N)
C-    N  EQUALS THE NUMBER OF RINGS PER SPOT BLOCK
      N=I2N/2
      DGND = 2.0 * RADUM
      HKAY  =  RBLOK(K) - SQRT(RBLOK(K)**2 - RASP**2)
      HPRIME = HKAY - RBLOK(K) + REFF(K) + 0.2500  + HCLR                       NEW
      IF (HPRIME .LE. 1.000)  HPRIME = 1.000 + HCLR
      S = HPRIME + DSUBP
      FLKAY = S - REFF(K)
       FKC = HPRIME + 3.000 - REFF(K)                                          CIM-X
      HDEE = 1.00 - HKAY + RBLOK(K) - REFF(K)
      IF (HPRIME .GT. 1.00)   HDEE = 0.25000
C-      FOR THE CONCAVE LENS, USE THE ROUTINE AFTER STATEMENT NO. 132
      IF (IND(K) .EQ. 2)  GO TO 132
      HBKA  =  HKAY + HDEE
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      WRITE (NPRINT,25) OASP, HBKA
      WRITE (NPRINT,29)  DBLANK, DPRING, REFF(K), CHI, BETA
      TILT = CHI - HBETA
      I  =  1
      IF (LIMP .NE. 2)  GO TO 940
      WRITE (NPRINT,54)
       GO  TO  950
  940 WRITE (NPRINT,34)
  950  CONTINUE
      IF (TILT .GE. 0.000)   GO TO 41
      WRITE (NPRINT,188)
      GO TO 40
   41 CONTINUE
      IF (TILT .GT. HBETA)   GO TO 44
       LPB = LPB + 1
C- THE FOLLOWING ESTABLISHES THE PARAMETERS FOR A CENTER LENS
       M  =  1
       POSANG = 0.000
       TILT = 0.0000
       ALPHA = 0.000
       X  =  0.000
       YOLO = REFF(K) + FLKAY + HPIVOT
      IF (LIMP .EQ. 1)  GO TO 42
      X  =  DSTT + HC                                                   CIM-X
      YOLD  =  DSTT + OEHT + FKC + REFF(K)                              CIM-X
   42 CONTINUE
      COTILT = 90.00
      WRITE (NPRINT,32)  I, COTILT, M, POSANG, X, YOLO, DEY(K)
         GO TO 40
   44 CONTINUE
      ANGLE = TILT / RTOD
      R = REFF(K) * SIN(ANGLE)
C-    IF (IND(K) .EQ. 2) R = SQRT(RTST(K)**2 - RBLANK**2) * SIN(ANGLE)
      ALPHA = 2.00 * RTOD * ASIN(RBC/R)
      XM = 360.0 / ALPHA
      M = IFIX(XM)
C-     M = NUMBER OF LENSES IN A GIVEN RING
      LPB = LPB + M
      POSANG=360.0/(FLOAT(M))
      X = FLKAY * SIN(ANGLE) + AXDIS * (1.00 - COS(ANGLE) )
      YOLD = REFF(K) + FLKAY * COS(ANGLE) + HPIVOT + AXOIS * SIN(ANGLE)
      XNEW  =  (DEHT + FKC) * SIN(ANGLE) + DSTT * COS(ANGLE)  + HC      CIM-X
      ZNEW  =  DSTT * (1.000 - SIN(ANGLE) ) + (DEHT + FKC) * COS(ANGLE) CIM-X
     1 + REFF(K)                                                        CIM-X
      COTILT = 90.00 - TILT
      IF (LIMP .NE. 2)  GO TO 48
      X  =  XNEW
      YOLO  =  ZNEW
   48  CONTINUE
      WRITE (NPRINT,32)  I, COTILT, M, POSANG, X, YOLD, DEY(K)
      TILT = TILT - BETA
      I  =  I  +  1
      IF (TILT .GE. 0.000)  GO TO 41
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      C-     NO CENTER LENS                              (CENTER LENS CANNOT BE FITTED IN)
             WRITE (NPRINT, 167)
                GO TO 40
      C-      *  *  *  *  *  *  *  *  *  *
        132 CONTINUE
      C-     CONCAVE LENS
      C-      *  *  *  *
                 I = 1
                 LPB = 0
      C-     CINCINATTI N.C. MILLING MACHINE   SUPLEMENT
            RSSKX = SQRT( (REFF(K) + 0.0500) ** 2 + RBLANK ** 2 )
            W3 = RPRING
            PHI = 80.00                                                    DEGREES
            IF (LIMP .NE. 2)  GO TO 181
            IF (REFF(K) .LT. ELL2)  GO TO 146
             CHIRAD = 80.00 / RTOD
            RADUM = RTST(K) * SIN(CHIRAD)
            IF (RADUM .LT. TOLMR)  GO TO 140
            PHI = ASIN(TOLMR/RTST(K))  * RTOD
               GO  TO  181
        140  CONTINUE
            PHI = 80.00                                                    DEGREES
               GO  TO  181
        146 CONTINUE
            PHI = 80.00                                                    DEGREES
            IF (REFF(K) .LT. ELL3)  GO TO 161
            OMCA = ACOS (W1 / RBLOK(K) ) * RTOD
            OMCAP = ASIN ((ELL2 - REFF(K))/RSSKX) * RTOD
            PHI = (HBETA + 90.00 + OMCAP) * 0.5000
            IF (OMCA .GT. OMCAP)  PHI = (HBETA + 90.0 + OMCA) *  0.5000
               GO  TO  181
        161    CONTINUE
            IF (ELL2  - REFF(K) .LT. RSSKX)  GO TO 175
            IF (ELL3  - REFF(K) .LT. RSSKX)  GO TO 164
            PHI = 80.00                                                    DEGREES
               GO  TO  181
        164    CONTINUE
            OMCA = 70.00 - HBETA
            OMCAP  =  ASIN((ELL3 - REFF(K)) / RSSKX) * RTOD
            PHI = 80.00                                                    DEGREES
            IF (OMCA .LT. OMCAP)  GO TO 181
            PHI = (HBETA + 90.00 + OMCAP) * 0.50000
               GO  TO  181
        175 CONTINUE
            OMCA = ACOS(W2/RBLOK(K) ) * RTOD
            OMCAP = ASIN((ELL3 - REFF(K))/RSSKX) * RTOD
            OMDUM = AMAX1(OMCA,OMCAP)
            PHI = (HBETA + 90.00 + OMDUM) * 0.50000
        181   CONTINUE
            CHI  =  PHI * 2.000
            KDUM = IFIX(CHI)
            PHI = FLOAT(KDUM) * 0.50000
            IF (LIMP .NE. 1)  GO TO 1190
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C-     CALCULATIONS FOR THE K+T INDEXING HEAD
       IF (REFF(K) .LT. ELL1)  GO TO 1140
       CHI = (ACOS((REFF(K) - ELL1) / RBLOK(K)) * RTOD + HBETA) *  .50 00
        RADUM = RTST(K) * SIN(CHI/RTOD)
       IF (RADUM .LT. TOLMR)  GO TO 1181
        CHI = ASIN(TOLMR / RTST(K)) * RTOD
        GO  TO  1181
  1140  CONTINUE
       IF (REFF(K) .LT. ELL2)  GO TO 1150
       OMCA = ASIN((ELL1 - REFF(K)) / RSSKX) * RTOD
       CHI = (HBETA + 90.00 + OMCA) * 0.5000
       RADUM  = RTST(K) * SIN(CHI/RTOD)
       IF (RADUM .LT. TOLMR)  GO TO 1181
       CHI = ASIN(TOLMR/ELL1) * RTOD
          GO  TO  1181
  1150  CONTINUE
       IF (REFF(K) .LT. ELL3)  GO TO 1220
       IF ((ELL1 - REFF(K)) . LT. RSSKX)  GO TO 1160
       OMCA = ACOS(W2 / RBLOK(K) ) * RTOD
       OMCAP = ASIN((ELL2 - RFFF(K)) / RSSKX) * RTOD
       OMDUM = AMIN1(OMCA,OMCAP)
       CHI = (HBETA + 90.00 + OMDUM)  * 0.5000
          GO  TO  1181
  1160  CONTINUE
       OMCA = ACOS(W1 / RBLOK(K)) * RTOD
       OMCAP = ASIN((ELL1-REFF(K)) / RSSKX) * RTOD
       IF (OMCA .LT. OMCAP)  GO TO 1170
       CHI = (HBETA + 90.00 + OMCAP) * 0.5000
          GO  TO  1181
  1170  CONTINUE
       OMCAP = ASIN((ELL2 - REFF(K)) / RSSKX) * RTOD
       OMDUM = AMAX1(OMCA,OMCAP)
       CHI = (HBETA + 90.00 + OMDUM)  * 0.5000
        GO  TO  1181
  1220  CONTINUE
C-        R SUB-E  .LT.  L-2
        IF (ELL2 - REFF(K) .LT. RSSKX)  GO TO 1250
        IF (ELL3 - REFF(K) .LT. RSSKX)  GO TO 1230
       CHI = 80.00                                                    DEGREES
          GO  TO  1181
  1230  CONTINUE
       OMCA = 70.00 - HBETA
       OMCAP = ASIN((ELL3 - REFF(K)) / RSSKX) * RTOD
       CHI = 80.000                                                    DEGREES
       IF (OMCA .GE. OMCAP)      CHI = (HBETA + 90.00 + OMCAP) * 0.500
          GO  TO  1181
  1250  CONTINUE
        OMCA = ACOS(W2 / RBLOK(K)) * RTOD
       OMCAP = ASIN((ELL3 - REFF(K)) / RSSKX) * RRTOD
       OMDUM = AMAX1(OMCA,OMCAP)
       CHI = (HBETA + 90.00 + OMDUM)  * 0.5000
  1181    CONTINUE
        CHEX = CHI * 2.000
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              KDUM = IFIX(CHEX)
              CHI = FLOAT(KDUM) * 0.5000
        1190  CONTINUE
C-            PRINT OUT PHI AND GO ON TO CALCULATE THETA OR TILT
               XDUM = SQRT((REFF(K) + 0.0500)**2 + RBLANK**2)
              IF (LIMP .EQ.1)    PHI = CHI
              CONDB  =  2.00 * XDUM * SIN(PHI/RTOD)
              DASP = 2.00 * RBLOK(K) * SIN(PHI/RTOD)
              HBKA = HKAY + HCLR + 1.00 + REFF(K) - RBLOK(K)
              WRITE (NPRINT,27)  DASP, CONDB, HBKA
              WRITE (NPRINT, 29)   DBLANK, DPRING, REFF(K), PHI, BETA
              IF ( LIMP .NE. 2)  GO TO 197
              WRITE (NPRINT,54)
                 GO  TO  199
         197  WRITE (NPRINT, 34)
         199   CONTINUE
C-            S = 8.250 + HPIVOT + RB(K) - REFF(K)
              RF = REFF(K) + 6.000
              FKC = REFF(K) + 4.000
C-              TILT IS FOR THE CIM-X N.C. MACHINE    AND/OR
C-                               K + T INDEXING HEAD
C-              TILT2 WAS FOR THE K+T INDEXING HEAD (ONLY)
               TILT  =  PHI - HBETA
C-            TILT2 = CHI - HBETA
         150   CONTINUE
              IF (TILT .LT. 0.000)  GO TO 144
              IF (TILT .GT. HBETA)  GO TO 142
                 LPB = LPB + 1
C- THE FOLLOWING ESTABLISHES THE PARAMETERS FOR A CENTER LENS
              M = 1
              POSANG = 0.000
              TILT = 0.000
              ALPHA = 0.000
              X = 0.000
              YOLD = REFF(K) + FLKAY + HPIVOT
              IF (LIMP .EQ. 1)  GO TO 149
              X  =  DSTT + HC                                        CIM-X
              YOLD  =  DSTT + DEHT + FKC - REFF(K)                   CIM-X
         149  CONTINUE
              COTILT = 90.00
              WRITE (NPRINT,32)  I, COTILT, M, POSANG, X, YOLD, DEY(K)
                    GO TO 89
         144  CONTINUE
C-             NO CENTER LENS                     (CENTER LENS CANNOT BE FITTED IN)
               WRITE (NPRINT, 167)
                    GO TO 89
         142    CONTINUE
              ANGLE = TILT / RTOD
              ANG2 = ANGLE
               R  =  SQRT(RTST(K)**2 - RBLANK**2) * SIN(ANGLE)
              ALPHA = 2.00 * RTOD * ASIN(RBC/R)
              XM = 360.0 / ALPHA
              M = IFIX(XM)
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C-       M = NUMBER OF LENS IN A RING
         LPB = LPB + M
         POSANG = 360.0 / FLOAT(M)
         X = RF * SIN(ANG2)  + AXDIS * (1.00 - COS(ANG2)  )
         YOLD = RF * COS(ANG2)  + AXDIS * SIN(ANG2)  + HPIVOT + REFF(K)
C-       XNEW = SX * SIN(ANGLE)                                          OPTIONAL
         XNEW  =  (DEHT + FKC) * SIN(ANGLF) + DSTT * COS(ANGLE)  + HC      CIM-X
         ZNEW  =  DSTT * (1.000 - SIN(ANGLE) ) + (DEHT + FKC) * COS(ANGLE)  CIM-X
        1  - REFF(K)
         YDUM = S - Y
         COTILT = 90.00 - TILT
         IF (LIMP .NE. 2)  GO TO 404
         X  =  XNEW
         YOLD  =  ZNEW
     404  CONTINUE
         WRITE (NPRINT,32)  I, COTILT, M, POSANG, X, YOLD, DEY(K)
         TILT = TILT - BETA
            I = I + 1
                GO TO 150
      89     CONTINUE
      40 CONTINUE
C-       TOTAL NUMBER OF LENSES ON THIS BLOCK
         WRITE (NPRINT,4)  LPB, K
C-       PRINT OUT THE GRINDER AND POLISHFR INFORMATION
         IF (IND(K) .NE. 2)   GO TO 58
         WRITE (NPRINT,36)  RGRIND,  DGND, HGRIND
         WRITE (NPRINT,37)  POLR, DPOL, HTPOL
          GO  TO  60
      58  CONTINUE
         IF (IND(K)  .NE. 1)    GO TO 60
         XDUM  =  1.100 * DGND
         WRITE (NPRINT,136) RGRIND, DGND, XDUM, HGRIND
         XDUM  =  1.100 * DPOL
         WRITE (NPRINT,137) POLR, DPOL, XnUM, HTPOL
      60        CONTINUE
         GO TO 1
         END
```

APPENDIX C

COMPUTER OUTPUT - COST COMPARISON

```
INPUT OATA =          2.5420      1.3000       .2500       .8870          1
   LENS BLANK DATA
        BLANK OIAMETER =     1.0000
        BLANK THICKNESS =      .2600
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    2.5420
        SPHERICAL RAOIUS OF BLOCK =    2.4390
        BLOCK DIAMETER =    4.8038
        BLOCK HEIGHT =    2.2654
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     2.2870
         PHI =  80.00
         BETA = 25.00
        RING      TILT      NO.OF     POSITION           K + T INOEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z          OELTA Z

          1       22.5000    13        27.6923      4.7256      9.1825       .0300
          2       47.5000     9        40.0000      3.3849     10.8143       .0300
          3       72.5000     3       120.0000      1.4801     11.7265       .0300
          NO CENTER LENS
             25 LENS ON BLOCK NO.  1

    GRINDER DATA-
        SPHERICAL RADIUS =   -2.5420
        GRINDER APERTURE (CONCAVE) =     5.0068
        GRINDER O.D. =    5.5074
        GRINDER HEIGHT =    3.1006
    POLISHER DATA-
        SPHERICAL RADIUS =   -2.6920
        POLISHER APERTURE (CONCAVE) =     5.3022
        POLISHER O.D. =    5.8324
        POLISHER HEIGHT =    3.2245

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =    1.3000
        SPHERICAL RAOIUS OF BLOCK =    1.3461
        BLOCK DIAMETER =    2.6514
        BLOCK HEIGHT =    1.3624
        DIAMETER OF HOLES (SPOTS) =    1.0000
        OIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     1.0829
         PHI =  80.00
         BETA = 50.00
        RING      TILT      NO.OF     POSITION           K + T INOEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z          OELTA Z

          1       35.0000     5        72.0000      4.3000      8.9766       .0497
          2       90.0000     1         0.0000      0.0000     10.8246       .0497
               6 LENS ON BLOCK NO.  2

    GRINDER DATA-
        SPHERICAL RADIUS =   -1.3000
        GRINDER APERTURE (CONCAVE) =     2.5605
        GRINDER O.D. =    2.8166
        GRINDER HEIGHT =    2.0743
    POLISHER DATA-
        SPHERICAL RADIUS =   -1.4500
        POLISHER APERTURE (CONCAVE) =     2.8559
        POLISHER O.D. =    3.1415
        POLISHER HEIGHT =    2.1982
```

```
INPUT DATA =          2.5420      1.3000      .2500      .8870          2
   LENS BLANK DATA
        BLANK DIAMETER =      1.0000
        BLANK THICKNESS =      .2600
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    2.5420
        SPHERICAL RADIUS OF BLOCK =    2.4390
        BLOCK DIAMETER =    4.8038
        BLOCK HEIGHT =    2.2654
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     2.2870
         PHI =  80.00
         BETA = 25.00
        RING     TILT      NO.OF    POSITION          CIM-X N.C. EQUIPMENT
         NO.     ANGLE     SPOTS     ANGLE          Y          Z         DELTA Z

         1      22.5000     13      27.6923     12.1970     5.1069       .0300
         2      47.5000      9      40.0000     11.7193     8.3146       .0300
         3      72.5000      3     120.0000      9.9308    11.0199       .0300
          NO CENTER LENS
             25 LENS ON BLOCK NO.  1

    GRINDER DATA-
        SPHERICAL RADIUS =  -2.5420
        GRINDER APERTURE (CONCAVE) =    5.0068
        GRINDER O.D. =    5.5074
        GRINDER HEIGHT =    3.1006
    POLISHER DATA-
        SPHERICAL RADIUS =  -2.6920
        POLISHER APERTURE (CONCAVE) =    5.3022
        POLISHER O.D. =   5.8324
        POLISHER HEIGHT =   3.2245

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =    1.3000
        SPHERICAL RADIUS OF BLOCK =    1.3461
        BLOCK DIAMETER =    2.6514
        BLOCK HEIGHT =    1.3624
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     1.0829
         PHI =  80.00
         BETA = 50.00
        RING     TILT      NO.OF    POSITION          CIM-X N.C. EQUIPMENT
         NO.     ANGLE     SPOTS     ANGLE          Y          Z         DELTA Z

         1      35.0000      5      72.0000     12.2893     5.6417       .0497
         2      90.0000      1       0.0000      8.0701    11.3221       .0497
               6 LENS ON BLOCK NO.  2

    GRINDER DATA-
        SPHERICAL RADIUS =  -1.3000
        GRINDER APERTURE (CONCAVE) =    2.5605
        GRINDER O.D. =    2.8166
        GRINDER HEIGHT =    2.0743
    POLISHER DATA-
        SPHERICAL RADIUS =  -1.4500
        POLISHER APERTURE (CONCAVE) =    2.8559
        POLISHER O.D. =    3.1415
        POLISHER HEIGHT =    2.1982
```

```
INPUT DATA =          3.3500    -1.3000      .0460      .8870          1
   LENS BLANK DATA
        BLANK DIAMETER =     1.0000
        BLANK THICKNESS =      .1560
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    3.3500
        SPHERICAL RADIUS OF BLOCK =    3.2420
        BLOCK DIAMETER =    6.3855
        BLOCK HEIGHT =    2.9291
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     3.1990
         PHI =  80.00
         BETA = 18.00
        RING     TILT      NO.OF     POSITION          K + T INDEXING HEAD
         NO.     ANGLE     SPOTS      ANGLE          X          Z         DELTA Z

          1     19.0000     18       20.0000      4.7117     9.7764      .0363
          2     37.0000     15       24.0000      3.9155    11.0240      .0363
          3     55.0000     11       32.7273      2.7726    11.9645      .0363
          4.    73.0000      5       72.0000      1.3951    12.5058      .0363
          NO CENTER LENS
             49 LENS ON BLOCK NO.  1

    GRINDER DATA-
        SPHERICAL RADIUS =   -3.3500
        GRINDER APERTURE (CONCAVE) =    6.5982
        GRINDER O.D. =   7.2580
        GRINDER HEIGHT =    3.7683
    POLISHER DATA-
        SPHERICAL RADIUS =   -3.5000
        POLISHER APERTURE (CONCAVE) =     6.8937
        POLISHER O.D. =   7.5830
        POLISHER HEIGHT =    3.8922

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =  -1.3000
        SPHERICAL RADIUS OF BLOCK =    1.3042
        BLOCK APERTURE (CONCAVE) =    2.5688
        BLOCK O.D. (CONCAVE) =    2.9370
        BLOCK HEIGHT =    2.1570 (H))
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     1.3548
         PHI =  80.00
         BETA = 46.00
        RING     TILT      NO.OF     POSITION          K + T INDEXING HEAD
         NO.     ANGLE     SPOTS      ANGLE          X          Z         DELTA Z

          1     33.0000      6       60.0000      6.3390    10.3626      .0375
          2     90.0000      1        0.0000      0.0000    11.0945      .0375
              7 LENS ON BLOCK NO.  2

    GRINDER DATA-
        SPHERICAL RADIUS =    1.3000
        GRINDER DIAMETER =    2.5605
        GRINDER HEIGHT =   1.0743
    POLISHER DATA-
        SPHERICAL RADIUS =    1.1500
        POLISHER DIAMETER =    2.2651
        POLISHER HEIGHT =   1.0287
```

```
INPUT DATA =          3.3500    -1.3000       .0460       .8870         2
    LENS BLANK DATA
         BLANK DIAMETER =     1.0000
         BLANK THICKNESS =      .1560
    CALCULATIONS FOR SPOT BLOCK NO. 1
         SPHERICAL RADIUS, C1 =    3.3500
         SPHERICAL RADIUS OF BLOCK =    3.2420
         BLOCK DIAMETER =    6.3855
         BLOCK HEIGHT =    2.9291
         DIAMETER OF HOLES (SPOTS) =    1.0000
         DIAMETER OF CLEARANCE HOLES =     .8750
         EFFECTIVE RADIUS =     3.1990
          PHI =  80.00
          BETA = 18.00
```

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	CIM-X N.C. EQUIPMENT Y	Z	DELTA Z
1	19.0000	18	20.0000	12.0103	5.5152	.0300
2	37.0000	15	24.0000	11.9720	7.8173	.0300
3	55.0000	11	32.7273	11.2242	9.9950	.0300
4	73.0000	5	72.0000	9.8401	11.8349	.0300

```
           NO CENTER LENS
              49 LENS ON BLOCK NO.  1

     GRINDER DATA-
         SPHERICAL RADIUS =   -3.3500
         GRINDER APERTURE (CONCAVE) =     6.5982
         GRINDER O.D. =    7.2580
         GRINDER HEIGHT =    3.7683
     POLISHER DATA-
         SPHERICAL RADIUS =   -3.5000
         POLISHER APERTURE (CONCAVE) =     6.8937
         POLISHER O.D. =    7.5830
         POLISHER HEIGHT =    3.8922

    CALCULATIONS FOR SPOT BLOCK NO. 2
         SPHERICAL RADIUS, C2 =   -1.3000
         SPHERICAL RADIUS OF BLOCK =    1.3042
         BLOCK APERTURE (CONCAVE) =    2.5688
         BLOCK O.D. (CONCAVE) =     2.9370
         BLOCK HEIGHT =    2.1570 (H1)
         DIAMETER OF HOLES (SPOTS) =    1.0000
         DIAMETER OF CLEARANCE HOLES =     .8750
         EFFECTIVE RADIUS =     1.3548
          PHI =  80.00
          BETA = 46.00
```

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	CIM-X N.C. EQUIPMENT Y	Z	DELTA Z
1	33.0000	6	60.0000	14.2565	4.1921	.0375
2	90.0000	1	0.0000	8.0701	11.1850	.0375

```
              7 LENS ON BLOCK NO.  2

     GRINDER DATA-
         SPHERICAL RADIUS =    1.3000
         GRINDER DIAMETER =    2.5605
         GRINDER HEIGHT =    1.0743
     POLISHER DATA-
         SPHERICAL RADIUS =    1.1500
         POLISHER DIAMETER =    2.2651
         POLISHER HEIGHT =    1.0287
```

APPENDIX D

COMPUTER OUTPUT - TEST SPOT BLOCKS

```
INPUT DATA =          2.5420     -1.2580       .2500       .8870          1
  LENS BLANK DATA
       BLANK DIAMETER =     1.0000
       BLANK THICKNESS =      .3636
  CALCULATIONS FOR SPOT BLOCK NO. 1
       SPHERICAL RADIUS, C1 =    2.5420
       SPHERICAL RADIUS OF BLOCK =    2.3376
       BLOCK DIAMETER =   4.6042
       BLOCK HEIGHT =   2.1817
       DIAMETER OF HOLES (SPOTS) =    1.0000
       DIAMETER OF CLEARANCE HOLES =     .8750
       EFFECTIVE RADIUS =    2.1834
        PHI =  80.00
        BETA = 26.00
       RING     TILT      NO.OF    POSITION          K + T INDEXING HEAD
        NO.     ANGLE     SPOTS     ANGLE          X         Z        DELTA Z

          1     23.0000    12      30.0000      4.7224    9.1236      .0300
          2     49.0000     8      45.0000      3.2949   10.8014      .0300
          3     75.0000     2     180.0000      1.2763   11.6836      .0300
         NO CENTER LENS
            22 LENS ON BLOCK NO.  1

   GRINDER DATA-
       SPHERICAL RADIUS =   -2.5420
       GRINDER APERTURE (CONCAVE) =     5.0068
       GRINDER O.D. =    5.5074
       GRINDER HEIGHT =    3.1006
   POLISHER DATA-
       SPHERICAL RADIUS =   -2.6920
       POLISHER APERTURE (CONCAVE) =     5.3022
       POLISHER O.D. =    5.8324
       POLISHER HEIGHT =    3.2245

  CALCULATIONS FOR SPOT BLOCK NO. 2
       SPHERICAL RADIUS, C2 =   -1.2580
       SPHERICAL RADIUS OF BLOCK =    1.3582
       BLOCK APERTURE (CONCAVE) =    2.6751
       BLOCK O.D. (CONCAVE) =     3.2448
       BLOCK HEIGHT =   2.3218 (H1)
       DIAMETER OF HOLES (SPOTS) =    1.0000
       DIAMETER OF CLEARANCE HOLES =     .8750
       EFFECTIVE RADIUS =     1.5197
        PHI =  80.00
        BETA = 48.00
       RING     TILT      NO.OF    POSITION          K + T INDEXING HEAD
        NO.     ANGLE     SPOTS     ANGLE          X         Z        DELTA Z

          1     34.0000     5      72.0000      6.3994   10.7231      .0497
          2     90.0000     1       0.0000      0.0000   11.2593      .0497
             6 LENS ON BLOCK NO.  2

   GRINDER DATA-
       SPHERICAL RADIUS =    1.2580
       GRINDER DIAMETER =    2.4778
       GRINDER HEIGHT =   1.0396
   POLISHER DATA-
       SPHERICAL RADIUS =    1.1080
       POLISHER DIAMETER =    2.1823
       POLISHER HEIGHT =   1.0379
```

```
INPUT DATA =          2.5420      1.2580      .2500      .8870.       1
   LENS BLANK DATA
        BLANK DIAMETER =      1.0000
        BLANK THICKNESS =      .2600
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    2.5420
        SPHERICAL RADIUS OF BLOCK =    2.4390
        BLOCK DIAMETER =    4.8038
        BLOCK HEIGHT =    2.2654
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =    .8750
        EFFECTIVE RADIUS =    2.2870
         PHI =  80.00
         BETA = 25.00
        RING      TILT      NO.OF      POSITION            K + T  INDEXING HEAD
         NO.      ANGLE     SPOTS       ANGLE          X           Z          DELTA Z

          1      22.5000      13       27.6923       4.7256      9.1825      .0300
          2      47.5000       9       40.0000       3.3849     10.8143      .0300
          3      72.5000       3      120.0000       1.4801     11.7265      .0300
          NO CENTER LENS
             25 LENS ON BLOCK NO. 1

    GRINDER DATA-
        SPHERICAL RADIUS =   -2.5420
        GRINDER APERTURE (CONCAVE) =    5.0068
        GRINDER O.D. =    5.5074
        GRINDER HEIGHT =    3.1006
    POLISHER DATA-
        SPHERICAL RADIUS =   -2.6920
        POLISHER APERTURE (CONCAVE) =    5.3022
        POLISHER O.D. =    5.8324
        POLISHER HEIGHT =    3.2245

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =    1.2580
        SPHERICAL RADIUS OF BLOCK =    1.3089
        BLOCK DIAMETER =    2.5780
        BLOCK HEIGHT =    1.3316
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =    .8750
        EFFECTIVE RADIUS =    1.0409
         PHI =  80.00
         BETA = 52.00
        RING      TILT      NO.OF      POSITION            K + T  INDEXING HEAD
         NO.      ANGLE     SPOTS       ANGLE          X           Z          DELTA Z

          1      36.0000       4       90.0000       4.2487      9.0064      .0497
          2      90.0000       1        0.0000       0.0000     10.7891      .0497
             5 LENS ON BLOCK NO. 2

    GRINDER DATA-
        SPHERICAL RADIUS =   -1.2580
        GRINDER APERTURE (CONCAVE) =    2.4778
        GRINDER O.D. =    2.7256
        GRINDER HEIGHT =    2.0396
    POLISHER DATA-
        SPHERICAL RADIUS =   -1.4080
        POLISHER APERTURE (CONCAVE) =    2.7732
        POLISHER O.D. =    3.0505
        POLISHER HEIGHT =    2.1635
```

```
INPUT DATA =           1.9650    -2.1950       .1500      .9350        1
   LENS BLANK DATA
        BLANK OIAMETER =     1.0000
        BLANK THICKNESS =       .2177
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    1.9650
        SPHERICAL RAOIUS OF BLOCK =    1.8633
        BLOCK DIAMETER =    3.6700
        BLOCK HEIGHT =    1.7897
        OIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =     1.7523
         PHI =  80.00
         BETA = 33.00
        RING      TILT      NO.OF     POSITION            K + T INDEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z          DELTA Z

          1       26.5000     9       40.0000      4.6607     8.9956       .0300
          2       59.5000     5       72.0000      2.5773    10.9174       .0300
          NO CENTER LENS
             14 LENS ON BLOCK NO.  1

    GRINOER OATA-
        SPHERICAL RAOIUS =  -1.9650
        GRINOER APERTURE (CONCAVE) =     3.8703
        GRINDER O.D. =   4.2573
        GRINOER HEIGHT =    2.6238
    POLISHER DATA-
        SPHERICAL RAOIUS =   -2.1150
        POLISHER APERTURE (CONCAVE) =     4.1657
        POLISHER O.D. =    4.5823
        POLISHER HEIGHT =    2.7477

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RAOIUS, C2 =  -2.1950
        SPHERICAL RADIUS OF BLOCK =    2.2377
        BLOCK APERTURE (CONCAVE) =    3.8361
        BLOCK O.D. (CONCAVE) =    4.2201
        BLOCK HEIGHT =    3.0211 (H1)
        DIAMETER OF HOLES (SPOTS) =    1.0000
        OIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RAOIUS =    2.3604
         PHI =  59.00
         BETA = 27.00
        RING      TILT      NO.OF     POSITION            K + T INOEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z          DELTA Z

          1       44.5000     9       40.0000      6.0752    13.1752       .0647
          2       71.5000     3      120.0000      2.6722    15.0952       .0647
          NO CENTER LENS
             12 LENS ON BLOCK NO.  2

    GRINDER DATA-
        SPHERICAL RADIUS =    2.1950
        GRINDER OIAMETER =    4.3233
        GRINDER HEIGHT =   1.8138
    POLISHER OATA-
        SPHERICAL RADIUS =    2.0450
        POLISHER DIAMETER =    4.0279
        POLISHER HEIGHT =   1.6899
```

```
INPUT DATA =            1.9650      1.0625       .1500       .9350 -         1
   LENS BLANK DATA
        BLANK DIAMETER =      1.0000
        BLANK THICKNESS =      .1600
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RADIUS, C1 =    1.9650
        SPHERICAL RADIUS OF BLOCK =    1.9189
        BLOCK DIAMETER =    3.7796
        BLOCK HEIGHT =    1.8357
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =      .8750
        EFFECTIVE RADIUS =     1.8100
         PHI =   80.00
         BETA =  32.00
        RING      TILT      NO.OF     POSITION              K + T  INDEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z           DELTA Z

          1      26.0000     10       36.0000      4.6741      9.0115         .0308
          2      58.0000      5       72.0000      2.6886     10.9077         .0308
          3      90.0000      1        0.0000      0.0000     11.4636         .0308
             16 LENS ON BLOCK NO.  1

     GRINDER DATA-
        SPHERICAL RADIUS =  -1.9650
        GRINDER APERTURE (CONCAVE) =     3.8703
        GRINDER O.D. =    4.2573
        GRINDER HEIGHT =    2.6238
     POLISHER DATA-
        SPHERICAL RADIUS =  -2.1150
        POLISHER APERTURE (CONCAVE) =     4.1657
        POLISHER D.D. =    4.5823
        POLISHER HEIGHT =    2.7477

    CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =    1.0625
        SPHERICAL RADIUS OF BLOCK =    1.1922
        BLOCK DIAMETER =    2.3483
        BLOCK HEIGHT =    1.2352
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =      .9568
         PHI =  80.00
         BETA = 56.00
        RING      TILT      NO.OF     POSITION              K + T  INDEXING HEAD
         NO.      ANGLE     SPOTS      ANGLE          X          Z           DELTA Z

          1      38.0000      4       90.0000      4.1569      9.0750        .0647
          NO CENTER LENS
              4 LENS ON BLOCK NO.  2

     GRINDER DATA-
        SPHERICAL RADIUS =  -1.0625
        GRINDER APERTURE (CONCAVE) =     2.0927
        GRINDER O.D. =    2.3020
        GRINDER HEIGHT =    1.8780
     POLISHER DATA-
        SPHERICAL RADIUS =  -1.2125
        POLISHER APERTURE (CONCAVE) =     2.3882
        POLISHER O.D. =    2.6270
        POLISHER HEIGHT =    2.0020
```

```
INPUT DATA =        10000.0000       1.9650         .1500        .9350          1
   LENS BLANK DATA
         BLANK DIAMETER =     1.0000
         BLANK THICKNESS =      .1600

          SIDE NO. 1 IS PLANO


   CALCULATIONS FOR SPOT BLOCK NO. 2
         SPHERICAL RADIUS, C2 =    1.9650
         SPHERICAL RADIUS OF BLOCK =    1.9863
         BLOCK DIAMETER =   3.9122
         BLOCK HEIGHT =   1.8914
         DIAMETER OF HOLES (SPOTS) =   1.0000
         DIAMETER OF CLEARANCE HOLES =     .8750
         EFFECTIVE RADIUS =     1.8100
          PHI =  80.00
          BETA = 32.00
         RING       TILT      NO.OF     POSITION           K + T INDEXING HEAD
          NO.       ANGLE     SPOTS      ANGLE          X          Z          DELTA Z

          1        26.0000     10       36.0000      4.6193     8.9848       .0000
          2        58.0000      5       72.0000      2.6563    10.8560       .0002
          3        90.0000      1        0.0000      0.0000    11.4026       .0003
              16 LENS ON BLOCK NO.  2

    GRINDER DATA-
         SPHERICAL RADIUS =   -1.9650
         GRINDER APERTURE (CONCAVE) =     3.8703
         GRINDER O.D. =    4.2573
         GRINDER HEIGHT =    2.6238
    POLISHER DATA-
         SPHERICAL RADIUS =   -2.1150
         POLISHER APERTURE (CONCAVE) =     4.1657
         POLISHER O.D. =    4.5823
         POLISHER HEIGHT =    2.7477
```

```
INPUT DATA =      10000.0000      1.9650      .1500      .9350      1
   LENS BLANK DATA
        BLANK DIAMETER =    1.0000
        BLANK THICKNESS =     .1600

         SIDE NO. 1 IS PLANO


   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RADIUS, C2 =    1.9650
        SPHERICAL RADIUS OF BLOCK =    1.9863
        BLOCK DIAMETER =    3.9122
        BLOCK HEIGHT =    1.8914
        DIAMETER OF HOLES (SPOTS) =    1.0000
        DIAMETER OF CLEARANCE HOLES =     .8750
        EFFECTIVE RADIUS =    1.8100
         PHI =  80.00
         BETA = 32.00
        RING     TILT     NO.OF    POSITION          K + T INDEXING HEAD
         NO.     ANGLE    SPOTS     ANGLE         X          Z        DELTA Z

          1     26.0000    10      36.0000     4.6193     8.9848     .0000
          2     58.0000     5      72.0000     2.6563    10.8560     .0000
          3     90.0000     1       0.0000     0.0000    11.4026     .0000
              16 LENS ON BLOCK NO.  2

    GRINDER DATA-
        SPHERICAL RADIUS =   -1.9650
        GRINDER APERTURE (CONCAVE) =     3.8703
        GRINDER O.D. =    4.2573
        GRINDER HEIGHT =    2.6238
    POLISHER DATA-
        SPHERICAL RADIUS =   -2.1150
        POLISHER APERTURE (CONCAVE) =     4.1657
        POLISHER O.D. =    4.5823
        POLISHER HEIGHT =    2.7477
```

```
INPUT DATA =      10000.0000      1.9650      .1500      .9350      2
   LENS BLANK DATA
         BLANK DIAMETER =     1.0000
         BLANK THICKNESS =       .1600

          SIDE NO. 1 IS PLANO


   CALCULATIONS FOR SPOT BLOCK NO. 2
         SPHERICAL RADIUS, C2 =    1.9650
         SPHERICAL RADIUS OF BLOCK =    1.9863
         BLOCK DIAMETER =    3.9122
         BLOCK HEIGHT =    1.8914
         DIAMETER OF HOLES (SPOTS) =    1.0000
         DIAMETER OF CLEARANCE HOLES =     .8750
         EFFECTIVE RADIUS =     1.8100
          PHI =  80.00
          BETA = 32.00
         RING      TILT      NO.OF     POSITION          CIM-X N.C. EQUIPMENT
          NO.      ANGLE     SPOTS      ANGLE         Y          Z          DELTA Z

          1       26.0000      10      36.0000     12.2518     5.1049      .0000
          2       58.0000       5      72.0000     11.1351     9.1021      .0000
          3       90.0000       1       0.0000      8.0701    11.9001      .0000
               16 LENS ON BLOCK NO.  2

    GRINDER DATA-
         SPHERICAL RADIUS =  -1.9650
         GRINDER APERTURE (CONCAVE) =     3.8703
         GRINDER O.D. =    4.2573
         GRINDER HEIGHT =    2.6238
    POLISHER DATA-
         SPHERICAL RADIUS =  -2.1150
         POLISHER APERTURE (CONCAVE)      4.1657
         POLISHER O.D. =   4.5823
         POLISHER HEIGHT =   2.7477

ARGUMENT NEGATIVE
ERROR NUMBER    39    DETECTED BY SQRT
```

INPUT DATA = 6.0000 3.2500 .2500 1.0900 1

LENS BLANK DATA

BLANK DIAMETER = 1.2500

BLANK THICKNESS = .2600

CALCULATIONS FOR SPOT BLOCK NO. 1

SPHERICAL RADIUS, C1 = 6.0000

SPHERICAL RADIUS OF BLOCK = 5.8870

BLOCK DIAMETER = 9.7610

BLOCK HEIGHT = 2.8450

DIAMETER OF HOLES (SPOTS) = 1.2500

DIAMETER OF CLEARANCE HOLES = 1.1250

EFFECTIVE RADIUS = 5.7450

PHI = 56.00

BETA = 13.00

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	K + T INDEXING HEAD X	Z	DELTA Z
1	40.5000	21	17.1429	1.6405	12.0065	.0300
2	53.5000	17	21.1765	1.2540	12.2508	.0300
3	66.5000	11	32.7273	.8224	12.4019	.0300
4	79.5000	4	90.0000	.3679	12.4521	.0300

NO CENTER LENS

53 LENS ON BLOCK NO. 1

GRINDER DATA-

SPHERICAL RADIUS = -6.0000

GRINDER APERTURE (CONCAVE) = 9.9485

GRINDER O.D. = 10.9433

GRINDER HEIGHT = 3.6448

POLISHER DATA-

SPHERICAL RADIUS = -6.1500

POLISHER APERTURE (CONCAVE) = 10.1972

POLISHER O.D. = 11.2169

POLISHER HEIGHT = 3.7110

CALCULATIONS FOR SPOT BLOCK NO. 2

SPHERICAL RADIUS, C2 = 3.2500

SPHERICAL RADIUS OF BLOCK = 3.2326

BLOCK DIAMETER = 6.3671

BLOCK HEIGHT = 2.9213

DIAMETER OF HOLES (SPOTS) = 1.2500

DIAMETER OF CLEARANCE HOLES = 1.1250

EFFECTIVE RADIUS = 3.0214

PHI = 80.00

BETA = 24.00

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	K + T INDEXING HEAD X	Z	DELTA Z
1	22.0000	13	27.6923	4.6063	9.8229	.0326
2	46.0000	10	36.0000	3.3806	11.3612	.0326
3	70.0000	4	90.0000	1.6353	12.2679	.0326

NO CENTER LENS

27 LENS ON BLOCK NO. 2

GRINDER DATA-

SPHERICAL RADIUS = -3.2500

GRINDER APERTURE (CONCAVE) = 6.4013

GRINDER O.D. = 7.0414

GRINDER HEIGHT = 3.6856

POLISHER DATA-

SPHERICAL RADIUS = -3.4000

POLISHER APERTURE (CONCAVE) = 6.6967

POLISHER O.D. = 7.3664

POLISHER HEIGHT = 3.8096

```
INPUT OATA =          6.0000      3.2500      .2500      1.0900          2
   LENS BLANK DATA
        BLANK OIAMETER =     1.2500
        BLANK THICKNESS =     .2600
   CALCULATIONS FOR SPOT BLOCK NO. 1
        SPHERICAL RAOIUS, C1 =    6.0000
        SPHERICAL RAOIUS OF BLOCK =    5.8870
        BLOCK OIAMETER =    9.7610
        BLOCK HEIGHT =   2.8450
        DIAMETER OF HOLES (SPOTS) =    1.2500
        OIAMETER OF CLEARANCE HOLES =    1.1250
        EFFECTIVE RAOIUS =    5.7450
         PHI =  56.00
         BETA = 13.00
```

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	CIM-X N.C. EQUIPMENT Y	Z	DELTA Z
1	40.5000	21	17.1429	9.8040	9.0297	.0300
2	53.5000	17	21.1765	9.6877	10.1741	.0300
3	66.5000	11	32.7273	9.3169	11.2630	.0300
4	79.5000	4	90.0000	8.7107	12.2407	.0300

```
         NO CENTER LENS
            53 LENS ON BLOCK NO.  1

    GRINOER OATA-
        SPHERICAL RADIUS =  -6.0000
        GRINOER APERTURE (CONCAVE) =     9.9485
        GRINOER O.O. =  10.9433
        GRINOER HEIGHT =    3.6448
    POLISHER OATA-
        SPHERICAL RAOIUS =   -6.1500
        POLISHER APERTURE (CONCAVE) =    10.1972
        POLISHER O.O. =   11.2169
        POLISHER HEIGHT =    3.7110

   CALCULATIONS FOR SPOT BLOCK NO. 2
        SPHERICAL RAOIUS, C2 =    3.2500
        SPHERICAL RAOIUS OF BLOCK =    3.2326
        BLOCK OIAMETER =    6.3671
        BLOCK HEIGHT =   2.9213
        OIAMETER OF HOLES (SPOTS) =    1.2500
        OIAMETER OF CLEARANCE HOLES =    1.1250
        EFFECTIVE RAOIUS =     3.0214
         PHI =  80.00
         BETA = 24.00
```

RING NO.	TILT ANGLE	NO.OF SPOTS	POSITION ANGLE	CIM-X N.C. EQUIPMENT Y	Z	OELTA Z
1	22.0000	13	27.6923	12.0537	5.7201	.0326
2	46.0000	10	36.0000	11.6834	8.7575	.0326
3	70.0000	4	90.0000	10.1097	11.3818	.0326

```
         NO CENTER LENS
            27 LENS ON BLOCK NO.  2

    GRINDER OATA-
        SPHERICAL RADIUS =  -3.2500
        GRINOER APERTURE (CONCAVE) =     6.4013
        GRINDER O.D. =   7.0414
        GRINOER HEIGHT =    3.6856
    POLISHER DATA-
        SPHERICAL RAOIUS =   -3.4000
        POLISHER APERTURE (CONCAVE) =     6.6967
        POLISHER O.O. =    7.3664
        POLISHER HEIGHT =    3.8096
```

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